MST121/MS221 GM

The Open University

USING MATHEMATICS
EXPLORING MATHEMATICS

A Guide to Mathcad

A GUIDE TO MATHCAD

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4.1

Contents

A **Quick reference** guide is provided on the back page

How to use this Guide

A Guide to Mathcad is a reference manual describing the Mathcad commands and features used in MST121 and MS221 (the 'course'). It assumes that your computer is operating under *Windows 95*, *98* or a later version. If you have a different version of *Windows*, then your screen may look slightly different to the pictures shown, but Mathcad will operate in a similar way.

The contents are grouped into broad areas of Mathcad use.

◊ To find a particular piece of information, try the alphabetic listing in the **Glossary**, on page 4.

◊ To look up a Mathcad **error message**, turn to page 65 at the back of this Guide.

The back page provides a summary of the key features of Mathcad in **quick reference** format.

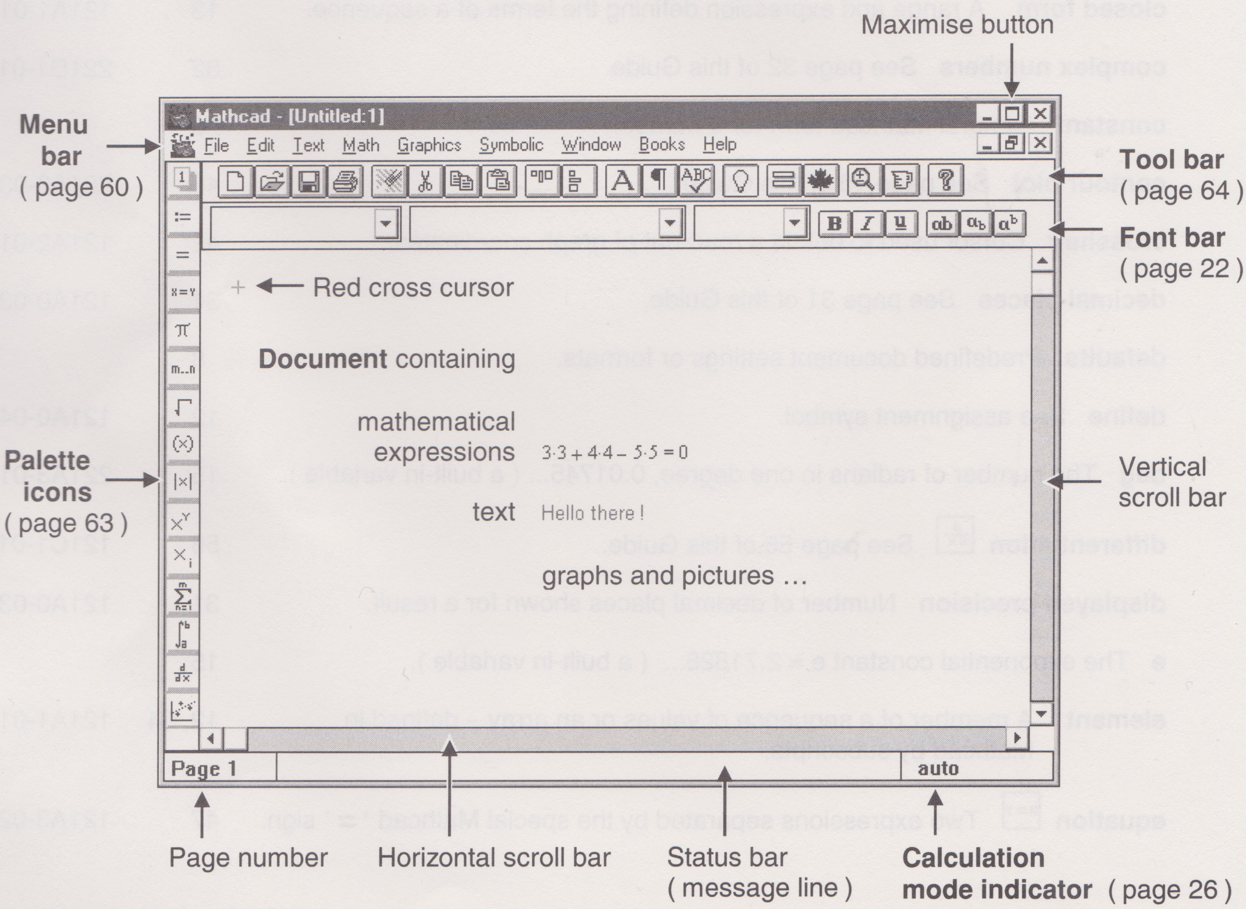
Notation

This Guide uses ♦ filled diamonds to indicate steps you should follow, and
! exclamation marks to highlight potential Mathcad problems.

Keystroke entry sequences are written in the style used in the course files.
For example – `[Ctrl]r` , with special keys shown enclosed within thin square brackets.

All mouse clicks refer to the left mouse button.

The Mathcad window



Glossary

Below is a glossary of terms used in the MST121 and MS221 Mathcad files and Computer Books. The right-hand columns give page references to the term in this Guide and file references to the Mathcad file in which the term is first used or explained.

argument	A value, variable or expression entered into a placeholder.	17	
array	General Mathcad term for a vector or matrix – a list of numbers.	54	121B2-01
assignment symbol	Palette icon used to define a variable or function.	12	121A0-04
automatic mode	Automatic calculation and updating of results.	26	
built-in function	Standard function predefined in Mathcad. Examples – cos, sin, tan, exp, ln and log.	15	
built-in variable	Special variable already defined when you start Mathcad. Examples – π, e and ORIGIN.	15	
calculation mode	Automatic (auto) or manual calculation mode.	26	
ceiling function / ceil(x)	Smallest integer which is greater than or equal to x.		121D1-01
clipboard	A temporary store to which information is cut or copied and from which information is pasted.		
closed form	A range and expression defining the terms of a sequence.	13	121A1-01
complex numbers	See page 32 of this Guide.	32	221D1-01
constant	General Mathcad term for a number.	26	
contour plot	See page 46 of this Guide.	46	221A3-03
crosshair	Cursor used to obtain a read-out of graph coordinates.	42	121A2-01
decimal places	See page 31 of this Guide.	31	121A0-03
defaults	Predefined document settings or formats.	8	
define	See assignment symbol.	12	121A0-04
deg	The number of radians in one degree, 0.01745... (a built-in variable).	15	221A3-01
differentiation	See page 56 of this Guide.	56	121C1-01
displayed precision	Number of decimal places shown for a result.	31	121A0-03
e	The exponential constant e = 2.71828... (a built-in variable).	15	
element	A member of a sequence of values or an array – defined in Mathcad by subscripts.	12, 54	121A1-01
equation	Two expressions separated by the special Mathcad ' **=** ' sign.	47	121A3-02

error message	See page 65 at the back of this Guide for advice.	65	
evaluate expression	Display the result of an arithmetic expression.	28	
Expand to Series...	A Symbolic menu command used to expand an expression to a Taylor series.	51	
exponential threshold	A setting which determines when numbers are shown in exponential (scientific) format.	31	121A0-03
expression	A number, formula or equation.	17	
Find	A Mathcad function to find the answer in the solve block method.	47	121A3-02
floor function / floor(x)	Greatest integer which is less than or equal to x.		121D1-01
font bar	The row of text formatting options below the menu and tool bars.	22	
format	The general appearance of text, numbers or graphs on the screen.	22, 30, 39	
function	See pages 14, 15 and 16 of this Guide.	14, 15, 16	
Given	A Mathcad keyword in the solve block method.	47	121A3-02
global format	A format applied to the whole document.	30	121A0-03
graph	See page 35 of this Guide.	35	
graph format	The appearance of a graph display. Examples – axis labelling, scale, trace type.	39	121A1-01
Greek letters	For details of how to enter, see pages 18 (expressions) and 23 (text) of this Guide.	18, 23	
grid lines	A grid of lines superimposed on a graph – a formatting option.	39	121A2-02
icon	A small button on the font bar, palette or tool bar.	22, 63, 64	
if	A Mathcad function for choosing one of two values based on a condition.	16	221B3-03
inherited values	See 'Re-defining variables' on page 15 of this Guide.	15	
input table	A column of figures entered by using a range variable and a subscripted variable.	13	
insertion point	A cursor (blue or red vertical bar |) used to enter and edit expressions and text.	19, 21	
integral	See page 56 of this Guide.	56	
interrupting calculations	[Esc] key – see page 27 of this Guide.	27	
keyboard short-cut	A sequence of key presses which select a command. (An alternative to selecting with a mouse click.)		
legend	Key to accompany a graph – a formatting option.	40, 41	
linebreak	A new line in a text box, created by pressing [↵].	21	
local format	The numerical format for an individual result or table.	30	121A0-03

manual mode Calculation and updating of results controlled by the user.	26	
markers Placeholders added to a graph to enable plotting of horizontal and vertical reference lines – a formatting option.	37	121A1-02
matrix See page 54 of this Guide.	54	121B2-01
menu A list of options from which you can choose a Mathcad command.	60	
message line Alternative name for the status bar.	3	
messy screen Refresh (re-draw) the screen to obtain an up-to-date view.	19	121A0-02
mod function / mod(a,n) The remainder of a on division by n.		221D2-01
numerical format Settings which control how results are shown. For example – the number of decimal places.	30	121A0-03
ORIGIN Specifies the subscript for the first element in a list or array. (A built-in variable.)	15	121A1-01
output General term to describe Mathcad results shown on the screen.	28	
output table A column of figures displayed by the use of a range variable.	29	121A3-01
pagebreak A solid or dotted horizontal line running across the screen indicating the start of a new page in a long document.	10	
palette A strip of icons at the left edge of the Mathcad window, used to enter mathematical operators and Greek letters.	63	
pi $\pi = 3.14159...$ (a built-in variable) .	15	121A0-04
placeholder A small black rectangle into which information is entered.	17	
polar plot See page 43 of this Guide.	43	221D1-01
polyroots A Mathcad function which returns all the roots of a polynomial.	48	221D1-02
printing See page 10 of this Guide.	10	
range variable $\boxed{m..n}$ A variable that takes on a range of values when used.	14	121A1-01
recurrence system A starting value, range and expression relating each term in a sequence to one or more previous terms.	27	121B1-01 221A1-01
refresh The process of re-drawing the screen, to obtain an up-to-date view.	19	121A0-02
region The area on the screen occupied by an expression, a graph, text or a picture. A Mathcad document is a collection of regions.	24	121A0-02
result format See numerical format.	30	121A0-03
rnd function / rnd(x) Generate a random number between 0 and x.		121D1-01
scalar A single number.		
scientific notation See exponential threshold.	31	121A0-03
scrolling table A table which scrolls to reveal all the values.	29	121A1-02

selection box	Blue box used to select parts of an expression or a graph.	19	
solve block	A numerical method to solve a system of equations.	47	121A3-02
Solve for Variable	A Symbolic menu command used to solve an equation.	51	121A3-03
status bar	Area at the bottom of the Mathcad window used for messages.	3	
subscripted variable $\boxed{x_i}$	See page 12 of this Guide.	12	121A1-01
Substitute for Variable	A Symbolic menu command to substitute an expression for a variable.	52	
surface plot	See page 44 of this Guide.	44	221A3-03
symbol	A data marker for graph points such as +, x (a formatting option).	39	121A1-01
symbolic calculations	See page 49 of this Guide.	49	121A0-05
table of values	A sequence of values displayed as a (scrolling) table.	29	121A1-01
text box	A box within which text may be inserted, edited or deleted.	21	121A0-01
text format	The appearance of text, e.g. bold, superscript.	22	
tick marks	Marks made on the axes of graphs to indicate the scales.	40	
toggle	Switch between two modes of Mathcad operation. For example – automatic / manual calculation.		
TOL	Determines the accuracy of some numerical methods. (A built-in variable.)	15	
tool bar	The row of icons immediately below the menu bar.	64	
trace	The line or symbols plotted on a graph.	40	121A1-01
trailing zeros	Zeros added to a number to display a fixed number of decimal places, e.g. 6.000 (a formatting option).	31	121A1-05
Undo	A command on the Edit menu to undo the last thing you typed.	60	
until	A Mathcad function to halt an iteration when a condition is met.	16	221D2-01
variable	A quantity that can vary ; it is represented by a variable name.	12	
vector	See page 54 of this Guide.	54	
word-processing	See page 21 of this Guide.	21	
x-y plot	A Cartesian graph – one with x- and y-axes !	35	121A1-01
zero tolerance	A setting to determine when numbers are shown as zero.	31	
Zoom (document)	A command on the Window menu to magnify or reduce the view of the entire document.	9, 60	
Zoom (graph)	A command on the X-Y Plot menu to magnify a portion of a graph.	42	121A3-01

Starting Mathcad

- ♦ Select the Start menu ; Programs ; MathSoft Apps ; and click on the Mathcad 5.0 icon.
  (See MST121 Chapter A0 for further details.)

General features of Mathcad documents

Mathcad documents consist of mathematical expressions (numbers, formulas and equations), graphs, text (words and sentences) and pictures.

These items can be placed anywhere in the document, and are created at the position marked by the red cross cursor. Each item forms a *region* in the document.

Mathcad processes the information in a document in the same way as you read it : from left to right and top to bottom, going down the screen line by line.

Documents may be longer than the one 'screenful' you can see in the Mathcad window. Use the vertical scroll bar or [`PageUp`] / [`PageDown`] keys to move up and down a document, to bring unseen parts into view.

Documents may also be wider than one 'screenful', with information placed beyond the right-hand margin or edge of the page (the solid and dotted vertical lines). Use the horizontal scroll bar to move left and right in a document.

On-screen help with using Mathcad is available from the menu bar. Select the **Help** menu and **Index...** to search for a particular topic, or select **Help** and **How Do I?...** for details of basic Mathcad procedures. Please note that this help is provided by MathSoft, the makers of Mathcad – it is NOT specific to MST121 and MS221.

Default document settings

The Mathcad documents supplied for MST121 and MS221 use the following default settings. (These settings will also be used for any new documents which you create yourself.)

Built-in variables ORIGIN has the value 0. (See page 15 of this Guide for further details.)

Calculation mode Automatic. (See page 26.)

Fonts and colours for text and mathematical expressions

◊ Text — Arial 10pt, dark blue.

◊ Expressions — Times Roman 10pt, black.

To change the fonts, do the following.

♦ Text — Select **Change Default Font...** from the **Text** menu.

♦ Expressions — Select **Modify Font Tag...** from the **Math** menu.
You need to 'modify the tag' for both Variables and Constants.

To change the colours, do the following.

- Select **Change Colors** from the **Window** menu.
  Choose the sub-option **Text Color...** or **Equation Color...** .

Graphs	Line graph ; the default trace is a solid red line. (See page 40.)
Numerical format	Displayed Precision 3 and Exponential Threshold 3. (See page 30.)

If any different default settings are used in a particular file, then there is a clear note on screen to that effect, explaining what changes to the settings have been made, and how.

Special features of MST121 and MS221 documents

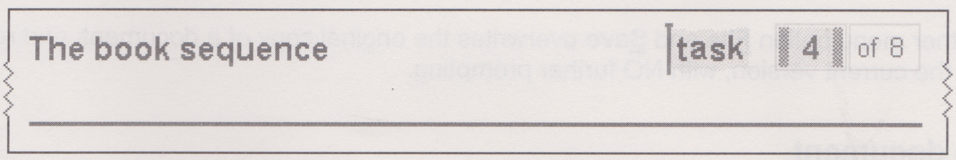
Document layout

The contents of MST121 and MS221 documents are divided up into a series of 'pages', with a title at the top and an end-of-document marker at the bottom. The documents fit within the *width* of the Mathcad window but most are *longer* than the window, consisting of several pages.

Your view of a course document will depend upon the size of computer screen you are using. A large (high-resolution) screen may show additional blank pages off to the right. To magnify your view, to see just one page width, use the **Window** menu and **Zoom...** option. (If you experience any problems with this option, then leave the zoom magnification at its normal value, 100%.)

The first page includes a list of contents, which may be accompanied by a brief introduction.

Subsequent pages each have a heading, a flag indicating the page 'type', a page number in the top right-hand corner, and a thick line marking the end of the page.

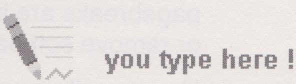


Getting around ...

- To move up and down within a page, use the vertical scroll bar or [`PageUp`] / [`PageDown`] keys, which, despite their names, actually move the red cross cursor only a few lines.
- To move through a document from one page to the top of another page :
  press [`Shift`][`PageUp`] to go to the previous page, [`Shift`][`PageDown`] to go to the next page ;
  or choose **Go to Page...** from the **Edit** menu, and enter the page number you require.

Entering your own expressions into the document

When a task requires you to enter information in a particular place, the 'pencil' symbol is used to show you the position on the screen at which to type.



Help

Assistance and explanations are provided on the pages within each course document, with hints and answers for the tasks, and detailed Mathcad instructions where appropriate.

Creating your own documents

♦ Select the **File** menu, and choose **New** to create a new, empty document.

A new document is also created automatically, ready for you to use, when you start Mathcad.

It is a good idea to enter some text in your documents (see page 21), alongside the mathematical expressions and graphs. Some explanatory text, including a title and date at the top, will help you to recall what the document was all about if you return to it on a later occasion.

When constructing a long document, you may like to divide it into separate pages.
(See Printing / pagebreaks at the bottom of this page.)

Opening, saving, printing and closing documents

Opening a document

♦ Select the **File** menu, and choose **Open...** .
(See MST121 Chapter A0 for more details.)

You can have up to nine Mathcad documents open at the same time if you wish !

Saving a document

♦ Select the **File** menu, and choose **Save As...** .
(See MST121 Chapter A0 for more details.)

Notes

The other menu option **File** and **Save** overwrites the original copy of a document, and replaces it with the current version, with NO further prompting.

Printing a document

! Please note
You will, on occasion, need to supply Mathcad print-outs for Tutor-Marked Assignments. However, you are NOT required to print out any of the course files (e.g. 121A1-01, -02, -03, ...).

◊ Print preview

To check your document's layout *before* printing, choose **Print Preview** from the **File** menu.

◊ Pagebreaks

A long document is automatically split into pages by Mathcad and your printer. These (soft) pagebreaks are indicated by dotted horizontal lines running across the screen. You cannot add or remove soft pagebreaks directly.

However, if you want to break the page at a different place, then you need to insert a (hard) pagebreak yourself. To do this, position the red cross cursor on the line where you want the break to be, then choose **Insert Pagebreak** from the **Edit** menu. These pagebreaks are shown as solid horizontal lines – you may have noticed them between the pages of the course documents. To remove a hard pagebreak : hold down the [`Shift`] key, and click on the 'kink' at the extreme left of the line to select it ; then use the **Edit** menu and **Cut**.

◊ Margins and wide documents

To set the margins, select the **File** menu and **Page Setup...** .
The right margin appears as a solid vertical line in the Mathcad window ; the dotted vertical line marks the edge of the sheet of paper itself.

A wide document, where information has been placed beyond the right margin, is divided into vertical strips of pages for printing purposes. Many of these pages may be blank, but they will still be churned out by the printer. To avoid printing any pages to the right of the right-hand margin, select **Print to Right Margin** in the 'Page Setup' option box.

Printing

♦ To print all or part of a Mathcad document, select the **File** menu and **Print...** .

This brings up the 'Print' option box. You can choose to print all of your document or only particular pages. Make sure that your printer is switched on and has some paper, then click on the **OK** button to print.

! After printing, Mathcad may appear to have wiped out some parts of your document from the screen. Don't worry : choose the **Window** menu and **Refresh**, or type [`Ctrl`]`r` to re-draw the screen display and restore the true view of your document.

Closing a document

♦ Select the **File** menu, and choose **Close**.

If you have made changes to the document since it was last saved, you will be asked if you wish to save the current version before closing.

Exiting from Mathcad

♦ Select the **File** menu, and choose **Exit**.
(See MST121 Chapter A0 for more details.)

Defining variables and functions

Defining variables

To **define** a variable, you assign a value to it – **variable name := value** , example $r := 1.5$

- Enter a name.
- Click on the palette 1 icon [:=] or use the keyboard equivalent **:** (colon – type [Shift];).
- Enter a value.
- To complete the definition, click elsewhere on the page or press the [↵] key.

Example $r \rightarrow$ [:=] $\rightarrow r := \blacksquare \rightarrow r := 1.5 \rightarrow r := 1.5$ or type **r:1.5**

A variable name can be a single letter, **r**, a letter followed by a number, **T1**, or a word, **step**. The name must start with a letter, and no spaces are allowed within the name. The underscore character _ (type [Shift]-) can be used as a separator instead of a space, e.g. **sunny_day**.

The value at the right-hand side of the definition must be a number. However, this number can be a constant or the result of a calculation, which in turn may also involve other variables and functions which have already been defined.

Examples $V := 71$ $\qquad V := 10 \cdot \pi \cdot 1.5^2$ $\qquad V := A \cdot h$

Variables must be defined *above* the place in the document where they are first used.
(On the same line and to the left counts as above, but to the right counts as below.)

If you try to use a variable before it has been defined, Mathcad highlights the unknown variable and displays the message 'Undefined variables shown in reverse' in the status bar at the bottom of the Mathcad window.

See Mathcad file 121A0-04, pages 3, 5 and 6.
Related topics in this Guide : Re-defining variables, page 15 ; Undefined variables, page 65.

Defining subscripted variables

To define a subscripted variable – **name** $_{\textbf{subscript}}$ **:= value** , example $u_3 := 16$

- Enter a name.
- Click on the palette 1 icon [X_i] or use the keyboard equivalent **[** (left square bracket).
- Enter a subscript.
- Click on the palette 1 icon [:=] or use the keyboard equivalent **:** (colon – type [Shift];).

- Enter a value.
- To complete the definition, click elsewhere on the page or press the [↵] key.

Example

$u \rightarrow \boxed{x_i} \rightarrow u_{\blacksquare} \rightarrow u_3 \rightarrow \boxed{:=} \rightarrow u_3 := \blacksquare \rightarrow u_3 := 16 \rightarrow u_3 := 16$ or type `u[3:16`

See Mathcad file 121A1-01, page 2.
Related topic in this Guide : ORIGIN, page 15.

Several subscripted variables can be defined at the same time by using a range variable as the subscript – three methods are given below. (See page 14 for details of range variables.)

◊ **Closed forms**

The range variable may be used on both sides of the definition for a subscripted variable to calculate the terms of a sequence. (The **closed form** formula makes up the right-hand side of the definition.)

For example

First term of the sequence has subscript 1 ORIGIN $:= 1$

Range $n := 1, 2 .. 12$ Definition $b_n := 5 + 3 \cdot (n - 1)$

Equivalent to $b_1 := 5$ $b_2 := 8$ ... up to $b_{12} := 38$

See Mathcad file 121A1-01, pages 4 and 5.

◊ **Input tables**

To enter a column of figures (an **input table**), create a definition for a subscripted variable, and enter the sequence of values separated by commas on the right-hand side of the definition.

As you type the comma, Mathcad inserts a new placeholder below ...

For example, type `P[i:1094,1500,1907,2070`

Range $i := 0, 1 .. 3$ $P_i := \blacksquare \rightarrow P_i := 1094 \rightarrow P_i :=$ $\begin{array}{|c|}\hline 1094 \\ \hline \blacksquare \\ \hline \end{array}$ Completed table $P_i :=$ $\begin{array}{|c|}\hline 1094 \\ \hline 1500 \\ \hline 1907 \\ \hline 2070 \\ \hline \end{array}$

Equivalent to $P_0 := 1094$ $P_1 := 1500$ $P_2 := 1907$ $P_3 := 2070$

Once an input table has been created, you can edit any of the existing values, insert extra values or delete values from the table. To insert a value, click on the value immediately above wherever you wish to place the new value. Then type a comma followed by the new number. You must also increase the final value of the range variable by one. Input tables are limited to 50 values.

◊ **Recurrence systems**, see page 27 of this Guide.

Defining range variables

To define a range variable – **name := starting value, next value .. final value**

Example i := 0, 1 .. 3

- Enter a name.
- Click on the palette 1 icon [:=] or use the keyboard equivalent **:** (colon – type `[Shift];`).
- Enter a starting value followed by a comma and the next value.
- Click on the palette 1 icon [m..n] or use the keyboard equivalent **;** (a semicolon).
- Enter the final value.
- To complete the definition, click elsewhere on the page or press the [↵] key.

Example i → [:=] → i := ▮ → i := 0, ▮ → i := 0, 1 → [m..n] → i := 0, 1 .. ▮ → i := 0, 1 .. 3

or type `i:0,1;3`

A range variable takes on a range of values, separated by uniform steps. In the example above, the variable **i** takes the values **0**, **1**, **2** and **3**. The step size is determined by the difference between the 'next value' and the 'starting value'.

An alternative way to think of and construct the definition is
name := starting value, starting value + step size .. final value

Range variables can ascend or descend in value, e.g. **i := 0, 1 .. 10** or **i := 10, 9 .. 0**
If the 'next value' is omitted, then Mathcad uses a step size of 1 or –1, whichever is appropriate.

See Mathcad files 121A1-01, page 3, and 121A2-02, page 6.

Related topics in this Guide :
Defining subscripted variables, page 12 ; Recurrence systems, page 27 ; Graphs, page 35.

Defining functions

To define a function – **function name := expression** , example $f(x) := 4 \cdot x^3$

The procedure is very similar to the one used to define a variable. (See page 12.)

- Enter a function name, followed by left round bracket '(', variable name, right bracket ')'.
- Click on the palette 1 icon [:=] or use the keyboard equivalent **:** (colon – type `[Shift];`).
- Enter an expression, which uses the named variable from the left-hand side.
- To complete the definition, click elsewhere on the page or press the [↵] key.

The expression on the right-hand side of the definition may include numbers, mathematical operators, variables and other functions which you have already defined or are built into Mathcad.

Example $y(t) := \sin(t) + \sin(13 \cdot t)$

This could be entered by the keystroke sequence `y(t):sin(t)+sin(13*t)`

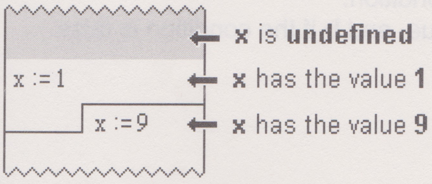
See Mathcad file 121A3-01, page 2.

Related topic in this Guide : Built-in or predefined functions, page 15.

Re-defining variables and functions

Variables and functions can be defined more than once in the same document.

A definition involving '**:=**' affects everything below and to the right of it in the document.



Mathcad will simply use the first definition for all expressions below the first definition and above the second.

For expressions below the second definition, Mathcad uses the second definition.

However, care is needed when re-defining sequences of subscripted variables. Suppose that the first definition creates ten terms, b_1, b_2, ..., b_{10}, but the second defines only five terms, b_1, b_2, ..., b_5. The values b_6, b_7, ..., b_{10} are still defined, as they are 'inherited' from the first definition.

One way to avoid any possible confusion is not to re-define subscripted variables !
Other types of variables and functions are not affected by this problem.

Built-in or predefined variables

There are a handful of special variables that are already defined when you start Mathcad. They either have a standard mathematical value, like π and **e**, or are used to control how Mathcad works, like **ORIGIN** and **TOL** (**Math** menu, **Built-In Variables...**).

Although Mathcad predefines these variables, you can still re-define them for your own use. Note that variable names are case-sensitive, e.g. ORIGIN must be entered in capital letters.

Variable	Default value	
π	3.14159...	Pi – click on the palette 1 icon $\boxed{\pi}$ or type [`Ctrl`]`p`
e	2.71828...	The exponential constant – simply type **`e`**
deg	0.01745...	The number of radians in one degree, e.g. $180 \cdot \mathrm{deg} = 3.14159...$
ORIGIN	0	Specifies the first element used for lists, tables and arrays.
TOL	0.001	Determines the accuracy of some numerical methods.

Notes

When working with subscripted variables, the value of ORIGIN should match the first subscript required. By default, Mathcad automatically begins each sequence with an element with a subscript zero, e.g. b_0. See Mathcad file 121A1-01, page 4.

Related topics in this Guide
ORIGIN : Defining subscripted variables, page 12 ;
Recurrence systems, page 27 ; Tables, page 29 ; Labelling matrix elements, page 54.
TOL : The solve block, page 48 ; Evaluating a definite integral numerically, page 58.

Built-in or predefined functions

Mathcad has an extensive library of built-in functions, including all the standard trigonometric, logarithmic and exponential functions. The complete list of functions can be seen by selecting the **Math** menu and **Insert Function**.

You can use the **Insert Function** option to insert a function into your document without having to type it. However, you still need to put the appropriate values into the placeholders yourself !

Alternatively, you can enter these functions directly, e.g. type **`cos(0.5)=`** .
Note that function names are case-sensitive : the built-in cosine function is cos(x), not COS(x).

Details of three of the special built-in functions used in MS221 are given below.
(In addition, the built-in functions **Find** and **polyroots** are described on pages 47 and 48.)

◊ **if**

The **if** function chooses one of two values based on a condition.
if(condition,a,b) returns the value **a** if the condition is true, and **b** if the condition is false.

Examples

$x := 7 \qquad \mathrm{if}\left(x>5, x^2, x\right) = 49$

$x := 3 \qquad \mathrm{if}\left(x>5, x^2, x\right) = 3$

Several if statements can also be combined together.

Example

$\mathrm{if}(p<0.8, f(x), \mathrm{if}(p<0.89, g(x), \mathrm{if}(p<0.98, h(x), k(x))))$

This expression returns :

$f(x)$ if $p < 0.8$; $g(x)$ if $0.8 \le p < 0.89$; $h(x)$ if $0.89 \le p < 0.98$; $k(x)$ if $p \ge 0.98$.

See Mathcad file 221B3-03, pages 3 and 4.

Related topic in this Guide : How to construct equations and inequalities, page 47.

◊ **until** (and **last**)

The **until** function is useful in iterative processes – it allows you to halt an iteration when a particular condition is met. **until(x,y)** returns **y** until the test expression **x** becomes negative.

The **last** function can then be used to detect when the iteration halted.
(**last(v)** gives the subscript of the last element in the vector **v**.)

Example

Calculation range $\quad n := 0, 1 .. 20$

Recurrence $\quad x_0 := 1 \quad$ and $\quad x_{n+1} := \mathrm{until}\left(100 - x_n, 2 \cdot x_n\right)$

$L := \mathrm{last}(x) - 1 \qquad L = 7 \qquad x_L = 128$

The expressions above calculate the values given by the recurrence

$x_0 = 1, \quad x_{n+1} = 2x_n \quad (n = 0, 1, 2, \ldots),$

until the 'test' $100 - x_n$ becomes negative, i.e. until $x_n > 100$.

When this point is reached, Mathcad sets the value of x_{n+1} to 0, and stops calculating further values of x_n. This final zero is a Mathcad peculiarity, so the last term in the iteration is actually given by **last(x) – 1**.

In some situations the until condition may never be reached. In such cases, the iteration will stop when the range variable reaches the final value specified in the calculation range.

See Mathcad file 221D2-01, page 3.

Related topic in this Guide : Recurrence systems, page 27.

Entering and editing expressions

Entering expressions

Entering expressions in Mathcad is a matter of putting information into a series of *placeholders*. These are the small black marks which appear as you click on the palette icons or use the equivalent keyboard commands.

A blue box surrounding the placeholder indicates that it is selected, ready to receive information.

Examples $y := \blacksquare$ $\quad u_{\blacksquare}$ $\quad j := 0, 1 .. \blacksquare$ $\quad \int_{\blacksquare}^{\blacksquare} \blacksquare \, d\blacksquare$

To select a particular placeholder, you can click on it.
If there are several placeholders, then the [`Tab`] key can also be used to select each in turn.

As you type information into a placeholder, the blue bar cursor (*insertion point*) appears.
If you make a mistake, then pressing [`Backspace`] will rub out the last number or letter you typed.

Examples $y := 5|$ $\quad u_{3}$ $\quad j := 0, 1 .. 100|$ $\quad \int_{\blacksquare}^{\blacksquare} \sin(x| \, d\blacksquare$

To finish entering an expression, you can either click elsewhere on the page or press the [↵] key.
(This key may also be labelled [`Return`] or [`Enter`].)

Dos and Don'ts
Do remember to include a multiplication sign where appropriate, e.g. enter ' `3*x` ' not ' `3x` '.
Don't use the spacebar in Mathcad expressions. The spaces look after themselves !

Division, powers, subscripts and the 'Up Arrow' key

Extra care is needed when entering expressions which involve division, powers or subscripted variables. After entering the division sign, `/`, typing continues in the denominator, below the line. In the case of powers, after entering `^`, typing continues above the line, whilst subscripts continue below the line, still within the subscript.

The 'Up Arrow' key [↑] is used to group (enclose in a blue selection box) parts of the expression typed so far. This enables typing to continue as usual (on the line) to construct the remainder of the expression. The number of presses of [↑] required depends upon the nature of the expression.

Examples	Key sequence	expression
	1/4[↑][↑]+6=	$\frac{1}{4}+6=6.25$
	x^2[↑][↑]-1	x^2-1
	F[n+1[↑][↑][↑]+F[n	$F_{n+1}+F_n$

See Mathcad files 121A0-03, page 3, and 221A1-01, page 3.

Greek letters in expressions

Greek letters can be used in expressions and as variable names in Mathcad.

Examples $\alpha:=2$ $\beta:=3$ $\theta:=\frac{\pi}{3}$ $\cos(\theta)=0.5$

There are two ways to enter a Greek letter.

A keyboard way.

- Type the roman equivalent, then press **[Ctrl]g**.
  For example, type **a** followed by **[Ctrl]g** – the 'a' will change into an 'α' (alpha) .

  The roman equivalents for the Greek letters used in the course files are :
  alpha α – a ; beta β – b ; pi π – p ; theta θ – q ; phi ϕ – f and psi ψ – y.

Or a mouse/click way.

- Click on the Greek letter icons in palettes 4 and 5.
  (To reveal these palettes, click on the number button **1**, then **2**, then **3** at the top.)

Notes

The Greek letter pi, π = 3.14159..., is a built-in variable in Mathcad. (See page 15.)

As π is so frequently used, there is a keyboard short-cut **[Ctrl]p**, and the $\boxed{\pi}$ icon is on palette 1.

All the methods above can also be used to enter Greek letters in Mathcad text (see page 23), with the exception of the keyboard short-cut for π, which is available only for expressions.

Related topics in this Guide : Palette icons, page 63 ; Defining variables, page 12.

Inserting or deleting blank lines in a document

You can easily insert one or more blank lines into your document, to create more space for any extra expressions. The same option is used to delete any surplus blank lines.

- Move the mouse arrow and click to position the red cross cursor just above the place where you wish to insert or delete the blank lines.
- Select the **Edit** menu, and choose **Ins/Del Blank Lines...** .
- Enter the number of blank lines required, and click **Insert** or **Delete** as appropriate.

See Mathcad file 121A0-02, page 3.

Related topic in this Guide : Moving regions, page 24.

Refreshing the screen for an up-to-date view

When you are using Mathcad, the screen will sometimes become confused by unwanted bits and pieces. Also, expressions and pieces of text might appear to go missing.

You can **refresh** (re-draw) the screen, to obtain an up-to-date view of what is really there.

- Select the **Window** menu, and choose **Refresh** or type the keyboard short-cut [`Ctrl`]`r`.

See Mathcad file 121A0-02, page 3.

Editing expressions : insertion-point and selection-box modes

There are two editing modes in Mathcad.

Insertion-point mode (the blue bar cursor) $x_n := \left(a + \frac{d}{r-1}\right)^n \cdot r - \frac{d}{r-1}$

Selection-box mode (a blue box) $x_n := \left(a + \boxed{\frac{d}{r-1}}\right)^n \cdot r - \frac{d}{r-1}$

In general, insertion-point mode is used for changing values, correcting typing mistakes and inserting extra information into an expression, whilst selection-box mode is useful for deleting or copying large parts of an expression.

- The first step is to click on the expression you wish to edit.

As an alternative to clicking on the expression, you can use the arrow keys to manoeuvre the red cross cursor over the expression, then press [↵].

You should then see either the blue bar or a blue selection box somewhere in the expression. If the bar or box is coloured red, then press the [`Ins`] key (this may be labelled [`Insert`]) to change it to blue.

To obtain the desired editing mode, do the following.

- **Insertion-point**
  Press the 'Down Arrow' key [↓] repeatedly until the blue bar cursor appears.

  The left and right arrow keys can be used to position the cursor within the expression.
  Pressing the [`Backspace`] key removes the number or letter to the left of the insertion point, whereas pressing [`Delete`] rubs out the character to the right.
  Any new information you type will appear immediately to the left of the insertion point.

- **Selection-box**
  Press the 'Up Arrow' key [↑].
  Once the selection box has appeared, subsequent presses of [↑] will enlarge the box, until it encloses the entire expression. Pressing [↓] will reduce the size of the selection box, until finally the blue bar cursor appears as Mathcad switches into insertion-point mode.

  Choosing the **Edit** menu and **Cut** (or pressing [`Ctrl`]`x`) will delete whatever part of the expression is enclosed by the blue selection box.
  The **Edit** menu **Copy** and **Paste** facilities can also be applied to the contents of the selection box, allowing you to copy part of an existing expression and paste it into a new one.

To finish editing an expression, you can either click elsewhere on the page or press the [↵] key.

There are no hard and fast rules regarding how to edit an expression. Use of the different editing modes is illustrated in the four basic editing techniques given on the next page.

Related topics in this Guide :
How to select a variable in an expression, page 50 ; How to select an entire expression, page 50.

How to change the value at the right-hand side of a definition

The example below uses **insertion-point** mode.

- ♦ Click on the right-hand side of the definition.
  If you get a blue box, keep pressing 'Down Arrow' [↓] until the blue bar cursor | appears.
- ♦ Use the left and right arrow keys to position the cursor as required [1].
- ♦ Rub out with the [`Backspace`] key [2] and enter the new value [3].
- ♦ Click elsewhere or press [↵] to finish [4].

1 r := 1.5| **2** r := 1| → r := ▮ **3** r := 2| **4** r := 2

How to change the operator (+ - * /) in an expression

The example below uses **selection-box** mode.

- ♦ Click on the operator you wish to change.
  If necessary, press the 'Up Arrow' key [↑] until the blue box surrounds the operator and the expressions either side of it [1].
- ♦ Press [`Backspace`] to delete the existing operator [2]. Type the new operator in its place [3].
- ♦ Click elsewhere or press [↵] to finish.

1 $y(x) := \boxed{a - b\cdot \exp(-k\cdot x)}$ **2** $y(x) := \boxed{a \,\square\, b\cdot \exp(-k\cdot x)}$ **3** $y(x) := \boxed{a + b\cdot \exp(-k\cdot x)}$

How to delete an entire expression

The example below uses **selection-box** mode.

- ♦ Click anywhere on the expression.
- ♦ If necessary, press the 'Up Arrow' key [↑] repeatedly,
  until the entire expression is enclosed in a blue box, as shown.

$$\boxed{x_n := \left(a + \frac{d}{r-1}\right)\cdot r^n - \frac{d}{r-1}}$$

- ♦ Then select the **Edit** menu and **Cut** (or press [`Ctrl]x`) to delete it.

How to change the value of a matrix element

The example below uses **insertion-point** mode.

- ♦ Click on the matrix element you wish to change.
  If you get a blue box, keep pressing 'Down Arrow' [↓] until the blue bar cursor | appears.
  (At this stage you can use the [`Tab`] key to move around the matrix elements in turn.)
- ♦ Use the left and right arrow keys to position the cursor as required [1].
- ♦ Rub out with the [`Backspace`] key [2] and enter the new value [3].
- ♦ Click elsewhere or press [↵] to finish [4].

1 $\begin{pmatrix} 4 & 6| \\ 2 & -1 \end{pmatrix}$ **2** $\begin{pmatrix} 4 & \blacksquare \\ 2 & -1 \end{pmatrix}$ **3** $\begin{pmatrix} 4 & 5| \\ 2 & -1 \end{pmatrix}$ **4** $\begin{pmatrix} 4 & 5 \\ 2 & -1 \end{pmatrix}$

See also Mathcad file 121B2-01, page 2.

Text and pictures

Creating text regions and entering text

Mathcad lets you enter text anywhere within a document, and also provides some basic word-processing facilities for formatting and checking the text.

In order to enter some text, you must first create a text region.
(If you just start typing, Mathcad thinks that you are entering a mathematical expression !)

- ♦ Click in a blank space in the document to position the red cross cursor where you wish the text region to begin.
- ♦ Select the **Text** menu, and choose **Create Text Region**.
  There is a keyboard short-cut for this command : type a double-quote `"` (given by [`Shift`]`2`).

  A small *text box* appears, with a red bar cursor inside – like this
- ♦ Now begin typing your text.

  As you type, the cursor (*insertion point*) moves and the text box grows automatically. The box will continue to expand until it reaches the right-hand margin of the document (the solid vertical line), when the text will wrap round to the next line below.

  To force a new line in the text box, press [↵] .
  (This key may also be labelled [`Return`] or [`Enter`].)
- ♦ To stop entering text, move the mouse arrow to a point outside the text region and click. The box will disappear, leaving just the text. You can also stop by pressing [`Shift`][↵].

Related topics in this Guide : Formatting text, page 22 ; Resizing a text region, page 25.

Text colour

By default, Mathcad uses dark blue for the text colour. To alter the colour, do the following.

- ♦ Select the **Window** menu and **Change Colors**, choosing the sub-option **Text Color...** .

Editing text

- ♦ To edit a piece of text, simply click on it !

  The text box and red bar cursor appear, allowing you to insert or delete text as you wish. (See the next page for details of how to delete a long string of text.)
- ♦ To finish editing text, move the mouse arrow to a point outside the text region and click. You can also finish by pressing [`Shift`][↵].

Notes

Use the left and right arrow keys, [←] and [→], to move the cursor along the text one character at a time, into the required editing position. Pressing [`Backspace`] will delete the character to the left of the cursor, whereas pressing [`Delete`] rubs out the character to the right.

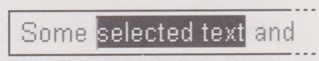
Any new characters you type will be inserted into the text immediately to the left of the cursor. Pressing [↵] will start a new line in the text box.

To replace existing text, press the [`Insert`] key, which switches between insert and overtype modes – the current mode is shown in the status bar at the bottom of the Mathcad window.

Selecting a string of text within a text region, to copy, delete or format

To select a string of text *within* a text region, prior to copying, deleting or formatting.

- ♦ Click in the text region so that the text box and red bar cursor appear. If necessary, use the arrow keys to manoeuvre the cursor to the start of the portion of text that you wish to select.
- ♦ Then hold down the mouse button and drag across the text. Mathcad highlights the selected text.



Once the text string has been selected, you can do the following.

- ◊ Use the **Edit** menu and **Copy** to copy the text string (to another text box). Click in the text region where the copy is to be inserted, and position the red bar cursor. Then choose the **Edit** menu again and **Paste**.
- ◊ Use the **Edit** menu and **Cut** to delete the text string. (You can use **Edit**, **Paste** to move this text to another location in a text box if you wish.)
- ◊ **Format** the text string – see the next section for details.

Notes – A single word in a text box can be selected by double-clicking on it.

Related topic in this Guide : Selecting regions to move, copy, delete or resize, page 24.

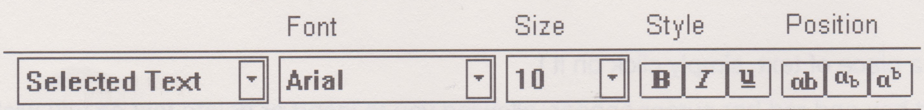
Formatting text

Once a text string has been selected, you can use the options on the **font bar** to format it, i.e. change its font, size, style and position.

- ◊ Font refers to the `typeface` used to write the text.
- ◊ Size refers to the size of the characters (measured in points, 72pt = 1 inch).
- ◊ Style refers to **bold**, *italic* or <u>underline</u> forms.
- ◊ Position refers to whether the text is normal, $_{\text{sub}}$scripted or $^{\text{super}}$scripted.

To format some text, follow the steps below.

- ♦ Select a text string within a text region – this can be just a single letter or number. (See the previous section in this Guide for details of how to do this.)
- ♦ Choose the formatting options you require from the font bar.



The font and size are chosen from the drop-down lists, whilst the style and position are set via the buttons on the right. You can set more than one style, e.g. ***bold and italic***, but only one position – the position button labelled **ab** represents normal text.

Notes

When you edit existing text in a text region (see page 21) and start typing, the new text takes its format from the character immediately preceding it.

! Warning – Formatting ALL the text in a document

The box at the left edge of the font bar shows the words 'Default Text' as text is entered, and changes to display 'Selected Text' once some text has been selected.

If NO text is selected, then any formatting will affect the 'Default Text' set-up, i.e. ALL the text in the document ! To reset these defaults, choose the **Text** menu and **Change Default Font...** .
(The settings used for course files are : font – Arial ; size – 10pt ; style – none ; position – normal.)

Typing Greek letters in text

There are two ways to enter a Greek letter within a text region.

A keyboard way.

- Type the roman equivalent, then press [`Ctrl`]`g`.
  For example, type `a` followed by [`Ctrl`]`g`. In the text box the 'a' will change into an 'α' (alpha) .

  The roman equivalents for the Greek letters used in the course files are :
  alpha α – a ; beta β – b ; pi π – p ; theta θ – q ; phi ϕ – f and psi ψ – y.

Or a mouse/click way.

- Click on the Greek letter icons in palettes 4 and 5.
  (To reveal these palettes, click on the number button **1**, then **2**, then **3** at the top.)

Note that the methods above are also used to enter Greek letters in mathematical expressions.

Related topic in this Guide : Palette icons, page 63.

Checking text for spelling mistakes

To check the text in Mathcad documents for spelling mistakes.
(Note that Mathcad checks only the text regions, it does NOT check mathematical expressions.)

- Select the **Text** menu and **Check Spelling...** .

If any misspelled words are found, Mathcad will display an option box and suggest a replacement.

Mathcad checks all the text regions beneath the red cross cursor to the end of the document.
You can also select a text string within a region to check. (See page 22 for selection details.)

Pictures

There are NO facilities within Mathcad itself for producing pictures or diagrams .

However, pictures can be created in other applications, such as the *Windows* Paint program, and pasted into Mathcad documents.

All the pictures you see in course documents, e.g. the pencil icon  , are bitmap graphics.

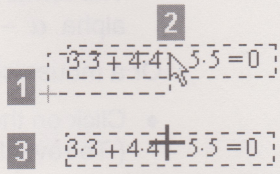
These pictures form regions in the document and can be moved, copied, deleted and even resized just like other Mathcad regions (see page 24 of this Guide). They are there only to be looked at – nothing happens if you click on a picture, apart from the appearance of the blue selection box around it ! Once a picture is selected in this way, you can choose the **Graphics** menu and **Picture Format...** to frame it.

Selecting regions to move, copy, delete or resize

How to select a region

Each mathematical expression, graph, piece of text and picture forms a **region** in a Mathcad document. Regions can be moved around the page, copied, deleted and (in the case of graphs and text) resized.

Before you can do any of these operations, you must **select** the region, or regions, you require.



- Click a little **away** from the region to obtain the **red cross cursor** [1].
- Click and drag (hold down the mouse button whilst moving the mouse) towards the region until it is enclosed by a **black dashed rectangle** [2].
- Release the mouse button [3].

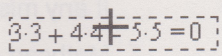
Notes

You can enclose more than one region in the black dashed selection rectangle.

This is a DIFFERENT technique from clicking **on** an expression or **in** a graph to enclose in a blue box. The blue selection box is used for editing expressions, and for formatting numerical results and graphs. (See page 19 of this Guide.)

How to move a region

- Select the region(s) in the way described above.
- Place the mouse arrow over a selected region to obtain a **black cross cursor**.
- You can now click and drag to move it to another location.



Cutting, copying and pasting regions

Once a region has been selected, all the standard *Windows* **cut**, **copy** and **paste** facilities are available.

- Select the region(s) you require. (See the top of this page for details.)
- Choose the **Edit** menu and **Cut** (`[Ctrl]x`) or **Edit** and **Copy** (`[Ctrl]c`).
  You can then position the red cross cursor elsewhere in the document, and **Edit**, **Paste** (`[Ctrl]v`) to either move or copy the region(s) as you wish.

Notes

These techniques can also be used with parts of a mathematical expression enclosed by the blue selection box. (See Editing expressions, selection-box mode, on page 19 of this Guide.)

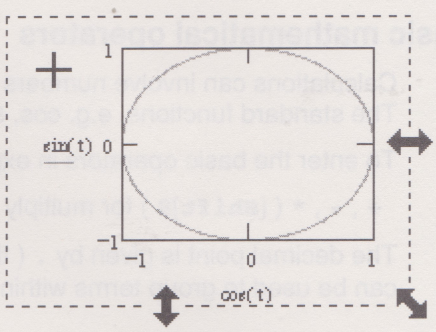
How to delete a region

- ♦ Select the region(s) you require. (See the previous page for details.)
- ♦ Choose the **Edit** menu and **Cut** (`[Ctrl]x`).

Resizing a graph

This technique involves changing the *physical* size of a graph, to make it look bigger or smaller on the page. It is not concerned with zooming in or out of the graph to get a different range of values, which is covered in 'Graphs – Zoom and crosshair' on page 42 of this Guide.

To change the size of a graph, do the following.



- ♦ Select the graph region so that it is enclosed by a black dashed rectangle as shown. (See the previous page for details.)

  Then release the mouse button.
- ♦ As you move the mouse pointer over the graph, it takes the different forms shown below.

  The effects of holding down the mouse button and dragging are as follows.

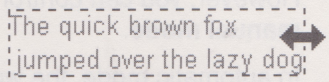
Change the height | Change the width | Change both height and width | Move the graph

See Mathcad file 121A2-02, pages 4 and 5.

Related topics in this Guide : Graph scaling, page 38 ; Graphs – Zoom and crosshair, page 42.

Resizing a text region

- ♦ Select the text region.
- ♦ Drag the mouse over the right-hand edge of the selection rectangle to change the width of the text region.



(See the technique for resizing a graph above for more details.)

Note that changing the width of a text region may also change its height, (i.e. the number of lines required to display the text), but you cannot change the height directly by dragging the mouse.

Related topic in this Guide : Entering text, page 21.

Resizing a (scrolling) table of values

For a large table of values, Mathcad switches automatically to a scrolling table. However, it may be possible to view all the values without scrolling by resizing the table.

- ♦ Select the table of values so that it is enclosed by a black dashed rectangle.
- ♦ Drag the mouse over the right-hand edge of the selection rectangle to change the width of the table, or drag over the bottom edge to change the height.

(See the technique for resizing a graph above for more details.)

See Mathcad file 221D2-02, page 2.

Related topic in this Guide : Tables of values, page 29.

Numbers – Calculations

Basic mathematical operators

Calculations can involve numbers (Mathcad calls these *constants*), variables and functions. The standard functions, e.g. cos, sin, ln, exp, ..., are built into Mathcad ; see page 15 of this Guide.

To enter the basic operators in expressions, type

`+` , `-` , `*` (`[Shift]8`) for multiply , `/` for divide, and `^` (`[Shift]6`) for powers.

The decimal point is given by `.` (the full stop), and round brackets `(` and `)`, `[Shift]9` and `[Shift]0`, can be used to group terms within an expression.

Dos and Don'ts
Do remember to include a multiplication sign where appropriate, e.g. enter ' `3*x` ' not ' `3x` '.
Don't use the spacebar in Mathcad expressions. The spaces look after themselves !

Related topic in this Guide : Entering expressions, page 17.

Calculation mode – automatic or manual

By default, Mathcad immediately (and automatically) calculates and updates all the results on the screen whenever values are entered or changed. This is **automatic mode**.

However, you can control calculations and changes to the screen display yourself, by switching to **manual mode**.

In automatic mode, the word 'auto' appears in the status bar in the bottom right corner of the Mathcad window.

- To put Mathcad into **manual** calculation mode, disable automatic mode by selecting the **Math** menu and choosing **Automatic Mode**. (The word 'auto' disappears from the status bar, and the tick mark beside Automatic Mode in the menu also disappears.)

  Once in manual mode, you calculate and update each separate screen as and when you choose, either by selecting **Calculate** from the **Math** menu, or by pressing the `[F9]` function key. It is also possible to update all the results, calculating every screen, by selecting **Calculate Document** from the **Math** menu

  If the results on the current screen are not up to date, then the words 'calc F9' appear on the status bar to remind you that re-calculation is required.

To switch back to automatic mode, select the **Math** menu and choose **Automatic Mode** again.

See MST121 Computer Book B, Chapter B1, and MS221 Computer Book B, Chapter B1.

Interrupting calculations

Mathcad evaluates the expressions in a document from left to right, going down a line at a time.

As Mathcad evaluates an expression, it covers the expression with a green cross-hatched rectangle. Most calculations occur so rapidly that this rectangle appears and disappears in the twinkling of an eye, and you are not able to see it. However, the rectangle may be visible during a lengthy or complicated calculation. The word 'WAIT' also appears in the status bar at the bottom of the window when Mathcad needs time to complete a calculation.

- To interrupt a calculation in progress, press [**Esc**], the Escape key.
  An option box appears ; click **OK** to stop the calculation, or **Cancel** to resume.

If you stop the calculation, then the expression that was being evaluated at the time is marked with the red error message 'Interrupted'. To complete this interrupted calculation later, first click on the expression, then choose **Calculate** from the **Math** menu or press the [**F9**] function key.

You may need to **refresh** the screen after the error message has been removed.
(See page 19 of this Guide for details.)

Notes

If you find yourself frequently interrupting calculations to avoid having to wait for Mathcad to re-calculate as you edit your document, then you may wish to switch to **manual** calculation mode.
(See page 26.)

Recurrence systems

To implement a recurrence system in Mathcad, you use a range variable to define a sequence of subscripted variables.

- If necessary, define the variable ORIGIN to match the subscript of the first element (1).
- Define a subscripted variable for the starting value, the first term of the sequence (2).
  This step may be interchanged with the next one.
- Define a range to calculate the desired number of terms (3).
  This will depend on the subscript used for the first term, which term the recurrence relation defines, e.g. b_n or b_{n+1}, and the number of terms required.
- Enter the recurrence relation, i.e. a definition for the terms of the sequence (4).
  Note that the range variable appears in the expressions for the subscripted variables.
  Mathcad carries out this definition once for each value of the range.

Examples

(1) $\mathrm{ORIGIN} := 1$ **(1)** ORIGIN is zero by default

(2) $b_1 := 5$

(3) $n := 1, 2 .. 11$ **(3)** $N := 20$ $i := 0, 1 .. N - 1$

(4) $b_{n+1} := b_n + 3$ **(2)** and **(4)** $P_0 := 3200$ and $P_{i+1} := P_i \cdot \left[1 + r \cdot \left(1 - \frac{P_i}{E}\right)\right]$

See Mathcad files 121B1-01 and 221A1-01.

Related topics in this Guide : Subscripted variables, page 12 ;
Defining range variables, page 14 ; ORIGIN, page 15 ; Entering expressions, page 17.

Numbers – Displaying results and formatting

Displaying results

The values of arithmetic expressions and all types of variables and functions may be displayed by clicking on the palette 1 icon [=] or typing = at the end of the expression.

Type	**Mathcad example** Definition	Key sequence to display	Result displayed on the screen
Expression	$2+3$	`2+3=`	$2+3=5$
Variable	$A:=30$	`A=`	$A=30$
Built-in variable	... already defined	`e=`	$e=2.718$
Subscripted variable	$v_8:=2$	`v[8=`	$v_8=2$
Sequence of subscripted variables	$ORIGIN:=1$ $n:=1,2..10$ $y_n:=1.1\cdot n+1$	`y=` A **table of values** See page 29 for further details.	$y = \begin{array}{c\|c} & 1 \\ \hline 1 & 2.1 \\ 2 & 3.2 \\ 3 & 4.3 \\ 4 & 5.4 \\ 5 & 6.5 \\ 6 & 7.6 \\ 7 & 8.7 \\ 8 & 9.8 \\ 9 & 10.9 \\ 10 & 12 \end{array}$
Range variable	$k:=0,1..3$	`k=` `k^2=` **Output tables** See page 29 for further details.	$\begin{array}{c} k \\ \hline 0 \\ 1 \\ 2 \\ 3 \end{array} \quad \begin{array}{c} k^2 \\ \hline 0 \\ 1 \\ 4 \\ 9 \end{array}$
Function values	$f(x):=4\cdot x^2-56\cdot x+192$	`f(3)=`	$f(3)=60$
Built-in function	... already defined	`sin([Ctrl]p/2)=`	$\sin\left(\frac{\pi}{2}\right)=1$

Tables of values

A sequence of values, e.g. y_1, y_2, y_3, ..., can be displayed as a (scrolling) **table of values**.

♦ Type the name of the sequence, e.g. **y**
immediately followed by clicking on the palette 1 icon [=] or typing = .

The appearance of the table depends upon the number of values it contains.
However, all the values in the sequence are displayed in each case.

◊ For sequences with nine values or less, Mathcad lists the values in order within round or square brackets. The first value in the sequence is shown at the top of the list.

◊ For sequences with ten or more values, Mathcad displays a recognisable table.

◊ When the sequence has a lot of values, Mathcad provides a scrolling table.
To access all the values, click once on the table to reveal the scroll bar.

Examples

$$y = \begin{bmatrix} 2.1 \\ 3.2 \\ 4.3 \\ 5.4 \\ 6.5 \end{bmatrix}$$

y =

	1
1	2.1
2	3.2
3	4.3
4	5.4
5	6.5
6	7.6
7	8.7
8	9.8
9	10.9
10	12

y =

	1
1	2.1
2	3.2
3	4.3
4	5.4
5	6.5
6	7.6
7	8.7
8	9.8
9	10.9
10	12
11	13.1
12	14.2
13	15.3
14	16.4
15	17.5

Note that the first value shown will depend on the value of ORIGIN. (See page 15 of this Guide.)

See Mathcad files 121A1-01, page 5, and 121A1-02, page 2.

Comparison of tables of values and output tables

Mathcad provides two types of table : a (scrolling) **table of values** and a (static) **output table**.
These tables offer two ways of looking at the same thing in Mathcad, a sequence of values.

◊ **Tables of values** are easy to display and always show all the values in the sequence. They fit neatly on the screen since Mathcad automatically creates a scrolling table for long sequences. (See the top of this page for more details.)

◊ An **output table** displays values in a long column. It does not scroll.
It must be preceded by a range variable. This range variable determines which values of the sequence are displayed. Although no more than 50 values can be shown in a single output table, you can choose a range to view a particular section of the sequence.
Output tables also provide a quick and easy way to display the results of calculations involving sequences, for example displaying the difference or ratio between successive terms.

Examples

Table of values

Type **y** then click $\boxed{=}$ or type = to display.

y =

	1
1	2.1
2	3.2
3	4.3
4	5.4
5	6.5
6	7.6
7	8.7
8	9.8
9	10.9
10	12

Output tables

Enter the expressions shown directly above each table, then click on the palette 1 icon $\boxed{=}$ or type = to display the table.

Display ranges

$i := 1, 2 .. 10$

i	y_i
1	2.1
2	3.2
3	4.3
4	5.4
5	6.5
6	7.6
7	8.7
8	9.8
9	10.9
10	12

$j := 1, 2 .. 5$

y_j
2.1
3.2
4.3
5.4
6.5

$k := 1, 2 .. 9$

$y_{k+1} - y_k$
1.1
1.1
1.1
1.1
1.1
1.1
1.1
1.1
1.1

Notes

When the expression being evaluated does not contain a range variable (y =), then the result is a **table of values**. But if the expression does involve a range variable (e.g. y_i =), then Mathcad shows the values in an **output table**. (The equals sign does not appear on the screen in an output table.)

See Mathcad files 121A1-01, page 5, 121A3-01, page 3, and 221A1-01, pages 4 and 5.

Formatting numbers

To control how Mathcad displays the results of numerical calculations, you set the **numerical format**. You can fix the **global** format, for every result in the document, or a **local** format for a particular expression or table.

Global format

- Select the **Math** menu followed by **Numerical Format**.

  The 'Numerical Format' option box appears.

- Click on the **GLOBAL** button if it is not already selected.

  (See the next page for details of other option box settings.)

⊙ GLOBAL
○ LOCAL

Local format

- Click anywhere in the result or table (an expression involving '=') that you want to format.
- Then select the **Math** menu, followed by **Numerical Format**.

  The 'Numerical Format' option box appears.
  Note that the **LOCAL** button is already selected.

  (Double-clicking on the right-hand side of the expression will also bring up the option box.)

Settings in the Numerical Format option box

◊ **Number Base or Radix**

Click on the Radix setting to set the base of the number system required.

Decimal	– Decimal (base 10)	Radix: ⦿ Decimal
Hex	– Hexadecimal (base 16)	○ Hex
Octal	– Octal (base 8)	○ Octal

◊ **Precision of Display**

To control how results are displayed on the screen, use the Precision box.

Notes

Mathcad retains 15 significant figures within memory for calculation purposes, independent of these precision settings.

Precision

Displayed Precision(3):	3	0 to 15
Exponential Threshold(3):	3	0 to 15
Complex Tolerance(10):	10	0 to 63
Zero Tolerance(15):	15	0 to 307

Displayed Precision (the default value is 3)

To set the number of decimal places, enter an integer *n* between 0 and 15.

See Mathcad file 121A0-03, page 4.

Exponential Threshold (the default value is 3)

To set the exponential threshold, enter an integer *n* between 0 and 15.
Mathcad displays the result in exponential or scientific notation.

When the threshold is 3, numbers above 1000 are displayed in exponential notation.
For example, the number 50000 will be displayed as $5 \cdot 10^4$.

See Mathcad file 121A0-03, page 4.

Zero Tolerance (the default value is 15)

To set the zero tolerance, enter an integer *n* between 0 and 307.
Numbers less than 10^{-n} will be displayed as zero.

◊ **Trailing Zeros** ☑ Trailing Zeros

With **Trailing Zeros** ON, all displayed results will have as many digits to the right of the decimal point as the Displayed Precision setting.

For example – with a Displayed Precision of 3, the number 6 will be displayed as 6.000 .

See Mathcad file 121A1-05.

◊ **Display as Matrix** ☑ Display as Matrix

With **Display as Matrix** ON, a (scrolling) table of values is changed to a matrix format.

Notes

Vectors and matrices with more than nine rows or columns are displayed as scrolling tables of values unless this option is ON.

Numbers – Complex numbers

Creating complex numbers

Mathcad accepts complex numbers of the form **x + yi**, where **x** and **y** are real numbers.
(There is NO multiplication sign between the '**y**' and the '**i**'.)

Examples	Key sequence	Complex number		
	`1+2i`	$1 + 2i$		
	`7-5i`	$7 - 5i$		
	`0.2+0.9i`	$0.2 + 0.9i$		
	`1i`	i		
	`3-1i`	$3 - i$		
		$a := 3 \quad b := 4$		
	`z:a+b*1i`	$z := a + b \cdot i$	Display	$z = 3 + 4i$

Notes

You cannot use **i** alone to represent the imaginary unit.
You must always type `1i` (if you don't, then Mathcad will incorrectly interpret the **i** as a variable).
The extra '1' in front of the **i** is visible only when entering or editing the complex number. It is hidden from view once the number is complete.

See MS221 Computer Book D, Chapter D1.

Arithmetic with complex numbers

The basic mathematical operators **+** , **-** , ***** , **/** and **^** can all be used with complex numbers.

Examples

Define $z := 3 + 4i$ and $w := 1 + 2i$

Evaluate $z + w = 4 + 6i$ $\quad z - w = 2 + 2i$ $\quad z \cdot w = -5 + 10i$

$\frac{1}{z} = 0.12 - 0.16i$ $\quad \frac{z}{w} = 2.2 - 0.4i$ $\quad z^2 = -7 + 24i$

Notes

When operating on complex numbers directly, you must enclose them within brackets.
For example $(3 + 4i) \cdot (1 + 2i) = -5 + 10i$

Expressions that involve only real numbers may also produce a complex value, e.g. $\sqrt{-1} = i$

Finding real and imaginary parts, complex conjugates and polar form

Mathcad provides some built-in functions and operators for working with complex numbers.

Real and imaginary parts

Function		Example	$z := 3 + 4i$
Re(z)	Real part of a complex number.	Type `Re(z)=`	$\mathrm{Re}(z) = 3$
Im(z)	Imaginary part of a complex number.	Type `Im(z)=`	$\mathrm{Im}(z) = 4$

Notes

Function names are case-sensitive in Mathcad.
You must type the capital letters 'R' and 'I' to begin the function names 'Re' and 'Im'.

Complex conjugates

To find the complex conjugate of a complex number $z := 3 + 4i$

- Type `z`, and select the entire expression. z
  (See page 50 of this Guide for selection details.)
- Then either click on the palette 2 icon $\overline{x}$ $\overline{z}$
  or type a double-quote `"` (given by [`Shift`]`2`).
- Finally, type `=` to evaluate the expression. $\overline{z} = 3 - 4i$

If you want to find a complex conjugate directly, remember to select the entire expression.
(Mathcad adds the brackets around 1+ 2i itself !) $1 + 2i \Rightarrow \boxed{1 + 2i} \Rightarrow \boxed{\overline{(1 + 2i)}} \Rightarrow \overline{(1 + 2i)} = 1 - 2i$

Polar form of complex numbers – modulus and argument

To find the polar form **< r, θ >** of a complex number $z := 3 + 4i$

Modulus

- Either click on the palette 1 icon $|x|$
  or type a vertical bar | (given by [`Shift`]`\`).
  Then type `z` followed by `=` to evaluate the modulus, **r**. $|z| = 5$

Argument

- Type `arg(z)=` to find the argument θ, in radians. $\arg(z) = 0.927$
  (Mathcad returns an angle between $-\pi$ and π.)

Exponential form of complex numbers

Example

Define	$r := \sqrt{2}$	and	$\theta := \frac{\pi}{4}$
Type `z:r*e^1i*q[Ctrl]g`	$z := r \cdot e^{i \cdot \theta}$		
Display	$z = 1 + i$		

Remember to enter the imaginary unit as `1i`, and to type the multiplication sign between 'i' and 'θ'.
(For more information about entering Greek letters in expressions, see page 18 of this Guide.)

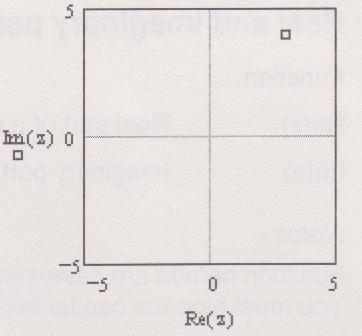
Drawing an Argand diagram

To represent a complex number **z** in Cartesian form z = a + bi on an Argand diagram.

- Simply create a standard **X-Y graph** (see page 35) and plot the point (**Re(z)**, **Im(z)**).
- Format the graph, setting the trace symbol to something visible, e.g. **box**. (See page 41.)
  The diagram can be enhanced by adding grid lines or axes, and scaling and resizing the graph.

Note that a complex number in polar form z = < r, θ > can be displayed on a polar plot. (See page 43.)

Example $z := 3 + 4i$



See MS221 Computer Book D, Chapter D1, and Mathcad file 221D1-01.

Related topics in this Guide :
Adding graph axes, page 37 ; Graph scaling, page 38 ; Resizing a graph, page 25.

Complex number solutions to equations

Both the **Symbolic** menu command **Solve for Variable** (see page 51) and the **polyroots** function (see page 48) will return ALL the roots of a polynomial equation at once, whether real or complex.

The examples below illustrate finding the roots of **$z^3 = 1$**.

Solve for Variable

$$z^3 = 1 \quad \text{has solution(s)} \quad \begin{bmatrix} 1 \\ \frac{-1}{2} + \frac{1}{2} \cdot i \cdot \sqrt{3} \\ \frac{-1}{2} - \frac{1}{2} \cdot i \cdot \sqrt{3} \end{bmatrix}$$

polyroots

Solve the equation $\mathbf{a_0 + a_1 z + a_2 z^2 + a_3 z^3 = 0}$

Define coefficients $a_0 := -1 \quad a_1 := 0 \quad a_2 := 0 \quad a_3 := 1$

Solution ... $\text{polyroots}(a) = \begin{pmatrix} -0.5 - 0.866i \\ -0.5 + 0.866i \\ 1 \end{pmatrix}$

Notes

The **polyroots** function will always return numerical values, while **Solve for Variable** returns the roots in symbolic form, e.g. expressions involving fractions and square roots, such as √3.

See MS221 Computer Book D, Chapter D1, and Mathcad file 221D1-02.

Related topic in this Guide : Solving equations, page 47.

Graphs – Drawing

How to create an X-Y graph

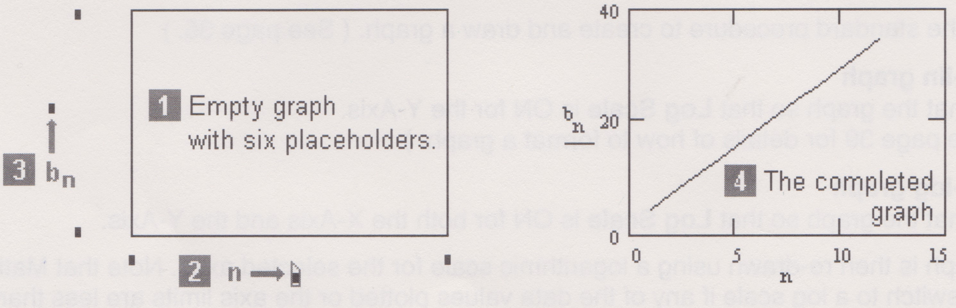
The same basic graph procedure is used to **plot** a **sequence** (see Mathcad file 121A1-01), a **curve described by parametric equations** (file 121A2-01), and a **function** (file 121A3-01).

Graphs are constructed with the use of range variables. (See page 14 of this Guide.)

Mathcad will plot one point for each value of the range variable used in the graph. So, prior to creating the graph itself, you must define a suitable range variable. This variable should then appear in both the x-axis and y-axis expressions used to plot the graph.

- Position the red cross cursor where you want the top left corner of the graph to be drawn.
- Either click on the graph icon at the bottom of palette 1, or type @ (`[Shift]'`).
- Mathcad creates an empty graph box [1].
  Enter the expression to plot on the x-axis into the middle placeholder on the horizontal axis [2].
  (Mathcad pre-selects this placeholder, ready for you to use.)
- Next enter the y-axis expression into the placeholder in the middle of the vertical axis [3].
  (To select this placeholder, either click with the mouse or press the `[Tab]` key three times.)
- Finally, click well outside the graph area, and Mathcad will calculate and plot the points [4].

In the example below, a range variable **n** is used to plot a sequence : the points (**n**, $\mathbf{b_n}$).



By default, Mathcad draws a line graph (see Graphs – Formatting, page 39) and automatically scales the graph axes, unless the other four placeholders are filled (see Graph scaling, page 38).

Exactly the same technique is used to plot a parametric curve, e.g. the points (**cos(t)** , **sin(t)**) with a graph range variable **t**, or a function, e.g. the points (**x**, **f(x)**) with a range variable **x**.

◊ **Keyboard short-cut for creating an X-Y graph**

There is a quick way to construct a graph by combining everything in one instruction :

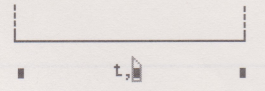
y-axis expression ; create graph ; **x**-axis expression.

For example, type `b[n@n`, then press [↵] to plot the points (**n**, $\mathbf{b_n}$) !

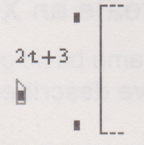
Plotting two (or more) curves on the same graph

To plot several curves on the same graph, enter the expressions for ‘x’ separated by **commas** on the x-axis, and likewise the ‘y’ expressions on the y-axis.

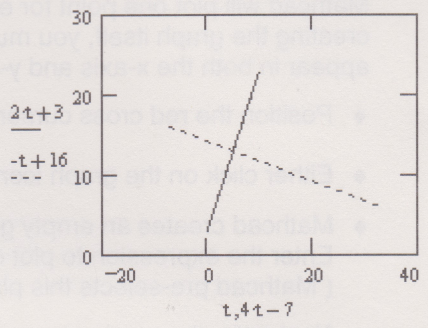
- Follow the standard procedure to create a graph. (See page 35.)
- Enter the first **x**-axis expression, followed by a **comma**.
  A second placeholder appears just to the right.
  Enter the second **x**-axis expression here, and so on.



- Select the placeholder in the middle of the **y**-axis.
- After typing the first **y**-axis expression followed by a **comma**, a second placeholder appears immediately below, ready for the second expression, and so on.



Mathcad matches up the expressions in pairs.
The first x-axis expression is plotted against the first y-axis expression, and the second against the second, and so on.
Traces (lines) are then plotted, one for each pair.



Notes

When plotting several y-axis expressions against the same x-axis expression, you need to enter the x-axis expression only once.

See Mathcad file 121A2-01, page 3.

Related topics in this Guide : Adding graph axes, page 37 ; Formatting graph traces, page 40.

Log-lin and log-log graphs

Follow the standard procedure to create and draw a graph. (See page 35.)

- **Log-lin graph**
  Format the graph so that **Log Scale** is ON for the Y-Axis.
  (See page 39 for details of how to format a graph.)
- **Log-log graph**
  Format the graph so that **Log Scale** is ON for both the X-Axis and the Y-Axis.

The graph is then re-drawn using a logarithmic scale for the selected axes. Note that Mathcad cannot switch to a log scale if any of the data values plotted or the axis limits are less than or equal to zero.

Adding graph axes

Mathcad does NOT draw lines for the graph axes automatically – you must add these yourself.
Two ways to do this are described below.
A third way is to format the graph so that **Grid Lines** are ON. (See pages 39 and 40.)

Plotting extra lines on a graph

- **X-axis** (the line y = 0)
  Define a suitable graph range **x**, and plot the points (**x**, **0**), i.e. put **x** in the placeholder on the horizontal axis, and **0** in the placeholder on the vertical axis.
- **Y-axis** (the line x = 0)
  Define a suitable graph range **y**, and plot the points (**0**, **y**).

There is no need to use variables called **x** and **y** here. Indeed, if the x- and y-axes have the same scale, then you can define a single graph range, say **s**, and plot the points (**s**, **0**) and (**0**, **s**).

Example

Plotting a function and adding both the x- and y-axes.

Enter `x,0,x` on the horizontal axis and `0,y,f(x)` on the vertical axis.

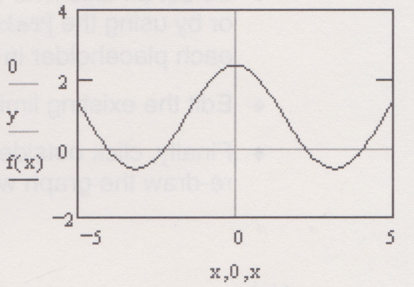
The lines drawn for the axes can be formatted to any colour and style. (See page 40.)

See also Mathcad file 221A2-02, page 3.

Related topic in this Guide :
Plotting two (or more) curves on the same graph, page 36.

Graph ranges

x := -5, -4.9 .. 5   y := -2, -1.9 .. 4



Formatting a graph using Show Markers

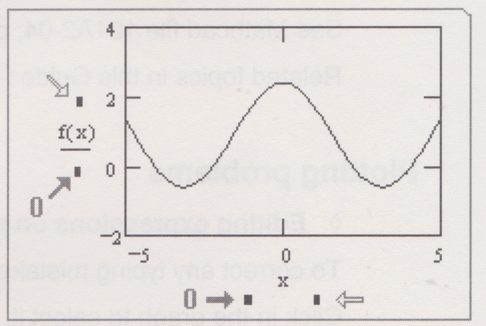
- Click **in** the graph to select it (graph surrounded by a blue selection box).
- Choose **Format...** from the **X-Y Plot** menu. Turn **Show Markers** ON.
  (See page 39 for further details about graph formatting.)

  Two extra placeholders appear on each axis.
- Click on one of these placeholders, and enter a number.

  For the **x**-axis,
  enter **0** in one of the placeholders on the **vertical** axis.

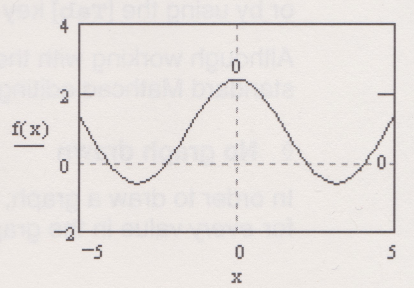
  For the **y**-axis,
  enter **0** in one of the placeholders on the **horizontal** axis.

  (The [`Tab`] key can also be used to select each graph placeholder in turn.)



- Finally, click outside the graph region to produce two dotted red marker lines for the axes.

  The format of these marker lines cannot be changed, and Mathcad also labels them with their values.



See Mathcad file 121A1-02, page 2.

Graph scaling

By default, Mathcad automatically scales the graph axes.

It chooses a 'nice' round number for each of the axis limits, ensuring that all the graph data is displayed within the graph box. If this data changes, then Mathcad automatically rescales the graph axes.

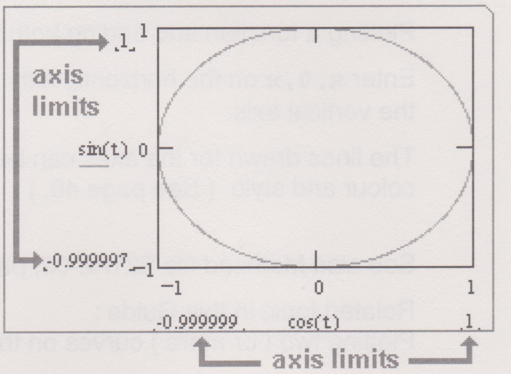
◊ **Autoscale** OFF (see Graphs – Formatting, page 39)

Mathcad still scales the graph automatically, but now sets the axis limits to the extreme values of the data, i.e. the traces plotted on the graph always extend to the edges of the graph box.

◊ **Fixing the scale**

The scale is fixed by entering values for the axis limits into the four placeholders at the ends of the axes. This can be done either when the graph is first created (when the graph box and all the placeholders are empty) or after the graph has been drawn – the situation shown below.

- Click **in** the graph to select it (graph surrounded by a blue selection box).
- Select an axis limit either by clicking on it or by using the [`Tab`] key to move along to each placeholder in turn.
- Edit the existing limit, and enter your new value.
- Finally, click outside the graph region to re-draw the graph with the new axis limits.



Notes

You can fix the value for one, two, three or all four of the axis limits.

To remove a fixed scale and let Mathcad automatically set the limits again, simply delete the existing limit value to leave an empty placeholder.

Mathcad may add or subtract tick marks or grid lines after rescaling.

See Mathcad file 121A2-04, page 4.

Related topics in this Guide : Graphs – Zoom, page 42 ; Resizing a graph, page 25.

Plotting problems

◊ **Editing expressions on the graph axes**

To correct any typing mistakes, change the expressions plotted or alter the graph scale.

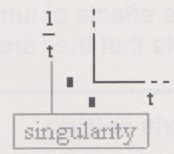
Click in the graph to select it, then select the expression you wish to change either by clicking on it or by using the [`Tab`] key to move along to each graph placeholder in turn.

Although working with the expressions on the graph axes is a bit like working in miniature, all the standard Mathcad editing techniques apply. (See page 19.)

◊ **No graph drawn**

In order to draw a graph, Mathcad must be able to evaluate the expressions on the x- and y-axes for *every* value in the graph range.

If Mathcad is unable to evaluate one of the expressions, it marks it with an error message (see page 65). The graph itself remains blank.



Suggested action – try a different graph range.

See MST121 Computer Book A, Chapter A3.

◊ **'Missing lines'**

A graph trace can be hidden under the edge of the graph box or by another trace. Alternatively, the data you are plotting may lie outside the chosen graph scale.

Suggested actions – try formatting the graph trace to mark the individual points with a symbol (see below) or alter the graph scale (page 38).

◊ **Scale and size**

Care is needed in interpreting what you see.

If the scales on the two axes are not identical, then the curves drawn will be distorted due to different scaling in different directions. For example, a circle may appear oval or elliptical.

See Mathcad file 121A2-02, pages 4 and 5.

Related topics in this Guide : Graph scaling, page 38 ; Resizing a graph, page 25.

Graphs – Formatting

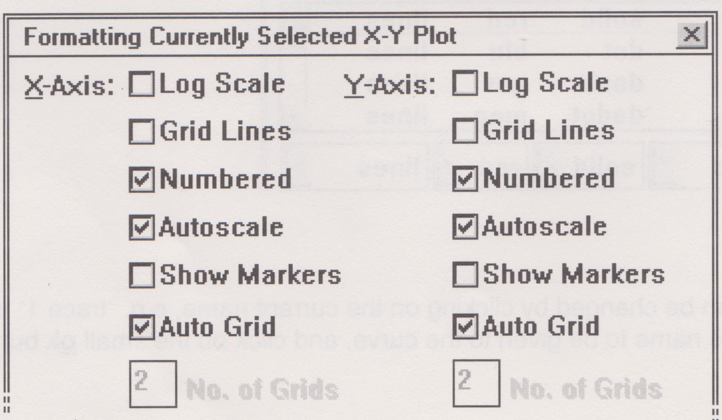
See Mathcad file 121A1-01, pages 7 and 8.

- Click **in** the graph to select it. Mathcad surrounds the graph region with a blue selection box and the **Graphics** menu is replaced by the **X-Y Plot** menu.
- Choose **Format...** from the **X-Y Plot** menu.
  Alternatively, double-click on the graph itself.

  This brings up the option box titled 'Formatting Currently Selected X-Y Plot'.
- Change the desired settings in the option box (see the next page for details) then click on the large **OK** button to see the results.

Axis settings

The diagram below shows the default settings used for the graph axes.



The effects of turning the axis options on or off are shown in the table below.
Note that they are shown in *alphabetical* order, and are set independently for the x- and y-axes.

Axis setting	Effect	Option box
Auto Grid ON	Mathcad selects the number of tick marks or grid lines.	☑ Auto Grid
Auto Grid OFF	You choose the number of grid lines (or tick marks) from 2 to 99. Log Scale should be off.	☐ Auto Grid 10 No. of Grids ☐ Log Scale
Autoscale ON	Mathcad rounds axis limits to 'nice' numbers.	☑ Autoscale
Autoscale OFF	The axis limits are set to the extremes of the data.	☐ Autoscale
Grid Lines ON	Grid lines in place of tick marks.	☑ Grid Lines
Grid Lines OFF	Tick marks in place of grid lines.	☐ Grid Lines
Log Scale ON	Axis is transformed to a logarithmic scale. See 'Log-lin graphs' on page 36 of this Guide.	☑ Log Scale
Numbered ON	Tick marks or grid lines are numbered on axis.	☑ Numbered
Show Markers ON	Adds reference lines to the plot. See 'Adding graph axes' on page 37 of this Guide.	☑ Show Markers

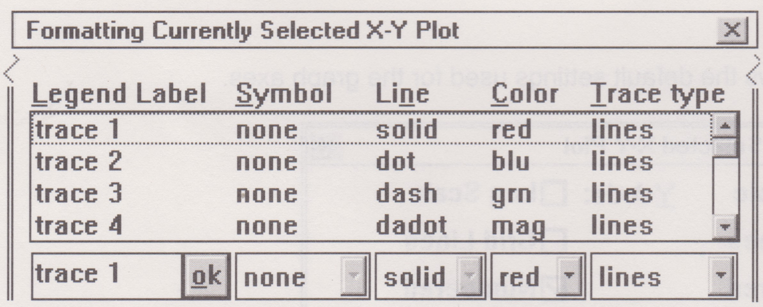
Trace settings

The trace settings control the colour and style used to plot the curves on a graph.

For example, to display a graph trace as individual points not joined together by a line, set the trace **Symbol** to **x's** and **Line** to **none**.

♦ To change the trace settings, click on the trace line and it will appear in the active window. The trace line chosen will be highlighted.

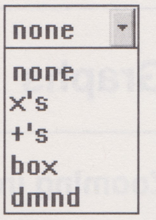
The picture below shows the trace line 'trace 1 none solid red lines' in the active window.



◊ **Legend Label**

The name of the curve can be changed by clicking on the current name, e.g. 'trace 1' in the active window. Type in the name to be given to the curve, and click on the small **ok** button.

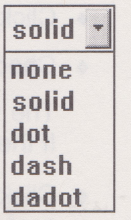
◊ **Symbol**



The plot symbol can be changed by clicking on the small down arrow in the **Symbol** column. This produces a drop-down list. ('dmnd' is a diamond.)

Click on the type of symbol required for each data point.
The active window will change to reflect this new symbol.

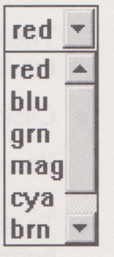
◊ **Line**



The line joining the data points can be changed by clicking on the small down arrow in the **Line** column. This produces a drop-down list of line styles. ('dadot' is short for dash-dot.)

Click on the desired line style, and it will appear in the active window.

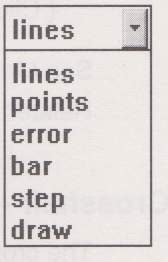
◊ **Color** (Note that Mathcad uses American spelling)



The colour of the trace can be changed by clicking on the small down arrow in the **Color** column. This produces a drop-down list of colours. ('mag' and 'cya' are short for magenta and cyan, i.e. purple and light blue colours.)

Click on a colour, and it will appear in the active window. The trace will be re-drawn using this colour once all the graph formatting is complete.

◊ **Trace type**



The trace type can be changed by clicking on the small down arrow in the **Trace type** column. This produces a drop-down list.

Click on the desired trace type, and it will appear in the active window.

Other settings

The remaining settings in the 'Format' option box control the display of axis labels and legends.

◊ **Hide Arguments** (Default OFF)

When this is ON, Mathcad hides the expressions on the axes used to plot the graph.

See Mathcad files 121B2-03, pages 3 and 4, and 221B1-01, page 2.

◊ **Hide Legend** (Default ON)

When this is OFF, Mathcad displays a legend (key) for the traces plotted on the graph.

Changing the global graph format

When you create a graph, it automatically gets the global (or default) graph format.
For example, by default Mathcad draws an X-Y graph as a line graph with a solid red trace.

If you intend to create many similar graphs in a document, you can set the global format to match.

- Create the first graph as usual, then resize and format it to your desired style.
  Then click in the check box labelled **Use for Defaults** in the 'Format' option box.

Each new graph will then be drawn using the size and format you specified for the first graph.

Graphs – Zoom and crosshair

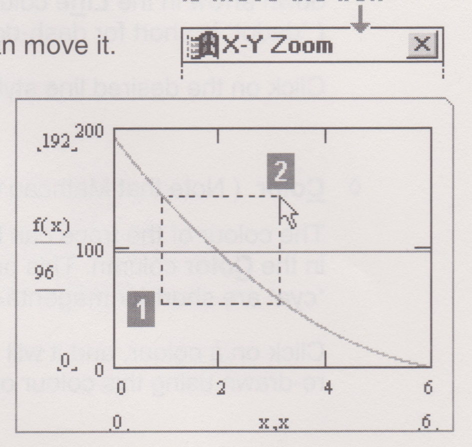
Zooming in on a graph

There are five steps to follow to zoom in and magnify a *portion* of a graph.

- Click in the graph to select it. Mathcad surrounds the graph with a blue selection box.
- Choose **Zoom...** from the **X-Y Plot** menu.

  The 'X-Y Zoom' option box appears.
  If the option box is covering part of your graph, then you can move it.

Click and drag
to move the box



- Click the mouse at the bottom left corner [1] of the area you want to magnify. Then drag the mouse arrow to the top right corner [2]. Release the mouse button.

  The coordinates of the selected area are listed in the 'Min:' and 'Max:' boxes in the option box.
- Click on the **Zoom** button to plot the selected area.

  You can repeat the last two steps to zoom in further.
- To finish zooming and to make the new axis limits permanent, click on the **Accept** button.

  (Clicking **Full View** will revert to the original graph.)

See Mathcad file 121A3-01, page 5.

Related topics in this Guide : Resizing a graph, page 25 ; Graphical solution, page 48.

Crosshair – getting a readout of graph coordinates

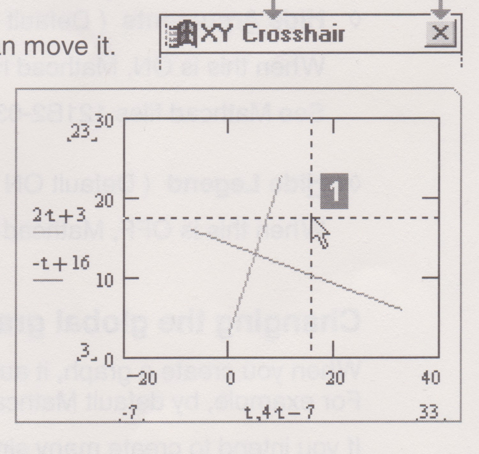
The crosshair is used to identify the coordinates of points on a graph.

- Click in the graph to select it. Mathcad surrounds the graph with a blue selection box.
- Choose **Crosshair...** from the **X-Y Plot** menu.

  The 'XY Crosshair' option box appears.
  If the option box is covering part of your graph, then you can move it.

Click and drag
to move the box

Close



- Click and drag the mouse arrow [1] in the graph box.

  A dotted crosshair follows your mouse pointer, and Mathcad displays the coordinates of the pointer in the 'X-Value' and 'Y-Value' boxes in the option box.
- To finish, close the 'XY Crosshair' option box, and click outside the blue box surrounding the graph to remove the crosshair.

Notes

The crosshair can be used in conjunction with the graph zoom option above, but you need to finish zooming and close the zoom option box before you can select the crosshair.

See Mathcad file 121A2-01, page 4.

Related topic in this Guide : Graphical solution, page 48.

Graphs – Polar plots

How to create a polar plot

The procedure to create a polar plot is similar to the one used to create an X-Y graph.

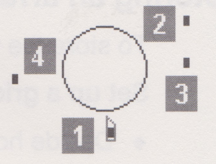
However, instead of entering expressions for x and y, a polar plot requires expressions for **r**, the distance from the origin, and **θ**, the angle made with a fixed base line through the origin.

- Position the red cross cursor where you want the top left corner of the plot to be drawn.
- Either choose **Create Polar Plot** from the **Graphics** menu, or type [`Ctrl`]7.
- Mathcad shows a circle with four placeholders.

  In placeholder [1] put the angle, **θ**.

  Placeholders [2] max and [3] min hold the limits for the radial scale.
  (Mathcad will scale the plot automatically if these are left empty.)

  In placeholder [4] put the expression for the distance, **r**.



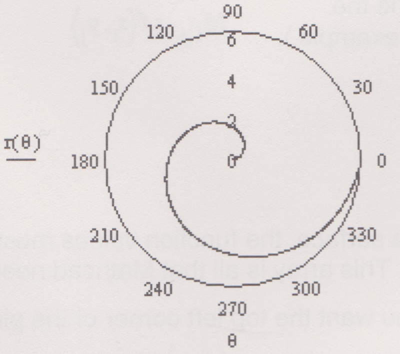
- Finally, click well outside the plot area. Mathcad will calculate and plot the points.

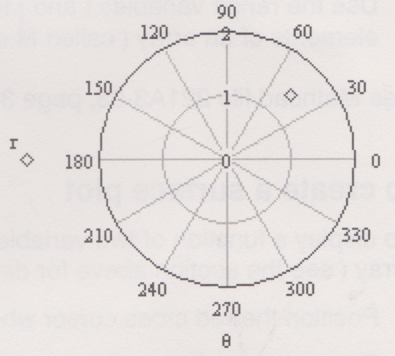
Examples

Function $r(\theta) := \theta$

Range $\theta := 0, 0.01 .. 2\cdot\pi$

Polar form of a complex number $z = < r, \theta >$ $\quad r := \sqrt{2} \quad \theta := \frac{\pi}{4}$





Notes

To enter the Greek letter theta θ, either use the palette 4 icon or type `q[Ctrl]g`.

See Mathcad file 221D1-01.

Related topic in this Guide : Graphs – Drawing, page 35.

Formatting a polar plot

You can format a polar plot in much the same way as formatting an X-Y graph.

- Click in the plot to select it. Mathcad surrounds the plot with a blue selection box.
- Choose **Format...** from the **Polar Plot** menu.
  Alternatively, double-click on the plot itself.

  This brings up the option box titled ‘Formatting Currently Selected Polar Plot’.
- Change the desired settings in the option box, then click the large **OK** to see the results.

  The settings are similar to the axis and trace settings used for an X-Y graph.
  (See page 39 of this Guide for further details.)

See Mathcad file 221D1-01.

Graphs – Surface and contour plots

Storing an array of values to plot

To store the values for a function of two variables in an array.

Set up a grid of points (x_i, y_j) — Example

- Decide how many $\mathbf{x_i}$ and $\mathbf{y_j}$ values to use, and define range variables **i** and **j** accordingly. — $i := 0, 1 .. 10$ $\quad j := 0, 1 .. 10$ $\quad$ 11 x 11 values
- Define $\mathbf{x_i}$ and $\mathbf{y_j}$ as two sequences of evenly spaced points on the axes. — $x_i := -5 + i$ $\quad y_j := -5 + j$ $\quad$ x- and y-values between –5 and 5

Store the function values for the grid points

- Use the range variables **i** and **j** to define the elements of an array (called **M** in this example). — $M_{i,j} := f(x_i, y_j)$

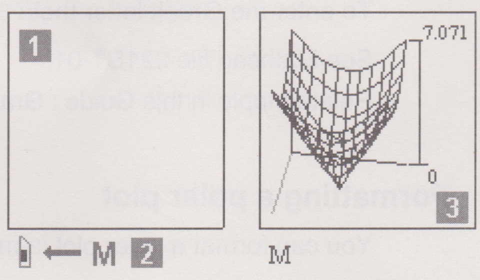
See Mathcad file 221A3-03, page 3.

How to create a surface plot

To display a function of two variables as a surface, the function values must first be stored in an array (see the section above for details). This array is all that Mathcad needs to plot the surface.

- Position the red cross cursor where you want the top left corner of the plot to be drawn.
- Either choose **Create Surface Plot** from the **Graphics** menu, or type [Ctrl]2.

  Mathcad creates an empty graph box with a single placeholder [1].
- Enter the name of the array into the placeholder [2].
- Click anywhere outside the plot region, and Mathcad will calculate and draw the surface [3].



See Mathcad file 221A3-03, page 3.

Formatting, scaling and resizing a surface plot

To format, or scale, a surface plot, do the following.

- Click on the surface to select it. Mathcad surrounds the plot with a blue selection box.
- Choose **Format...** from the **Surface Plot** menu (or double-click on the surface itself).

  This brings up the option box titled 'Surface Plot Format'.
- Change the desired settings in the option box, then click **OK** to see the results.

Surface plot – format settings

To change the perspective (point of view) from which you see a surface.

◊ **Rotation**
Increase this value to rotate the plot in a clockwise direction.
(Set the angle to an integer between 0 and 360 degrees.)

◊ **Tilt**
The tilt controls how high above the surface you are.
When it is set to 0 degrees, you are viewing the surface from the side (at ground-level).
When it is set to 90 degrees, you are looking straight down on the surface from above.

To scale the surface and control how bumpy it will be.

◊ **Vertical Scale**
Set the magnification factor to an integer between 1 and 100.
This determines the variations in height shown between the largest and smallest plot values.
(Mathcad always plots all the values in the array and sets the numerical scale automatically.)

The remaining format settings affect the appearance of the surface.

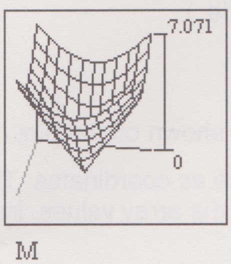
◊ The default settings are shown in the diagram below.

☐ Hide Lines
☐ Patch Plot
☑ Show Axes
☑ Show Border

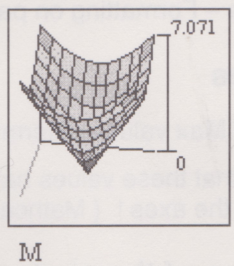
Shading:
○ Color Spectrum
⦿ White
○ Grayscale

Examples

Hide Lines ON
Shading: White



Hide Lines OFF
Shading: Color Spectrum



See Mathcad file 221A3-03, page 4.

◊ **Change to Contour**
Surface and contour plots can be drawn from the same array of values.
To transform the surface plot into a contour plot, click on this button, then click **OK**.

Resizing a surface plot

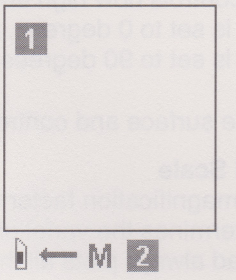
To change the *physical* size of a surface plot, to make it look bigger or smaller on the page, use the technique for resizing an X-Y graph (described on page 25 of this Guide).

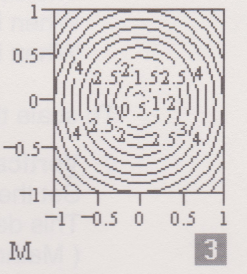
How to create a contour plot

To display a function of two variables as a contour plot, the function values must first be stored in an array (see the top of page 44 for details). This array contains all the information that Mathcad needs to draw the contour plot.

- ♦ Position the red cross cursor where you want the top left corner of the contour plot to be drawn.
- ♦ Either choose **Create Contour Plot** from the **Graphics** menu, or type [`Ctrl`]5.

  Mathcad creates an empty graph box with a single placeholder [1].
- ♦ Enter the name of the array into the placeholder [2].
- ♦ Click anywhere outside the plot region, and Mathcad will calculate and draw the contour plot [3].





See Mathcad file 221A3-03, page 3.

Formatting, scaling and resizing a contour plot

To format, or scale, a contour plot, do the following.

- ♦ Click on the contour plot to select it. Mathcad surrounds the plot with a blue selection box.
- ♦ Choose **Format...** from the **Contour Plot** menu (or double-click on the plot itself).

  This brings up the option box titled 'Contour Plot Format'.
- ♦ Change the desired settings in the option box, then click **OK** to see the results.

Axis settings

The **Grid Lines**, **Numbered** and **Auto Grid** options are identical to those for an X-Y graph. (See Graphs – Formatting on page 39 of this Guide.)

Axis scales

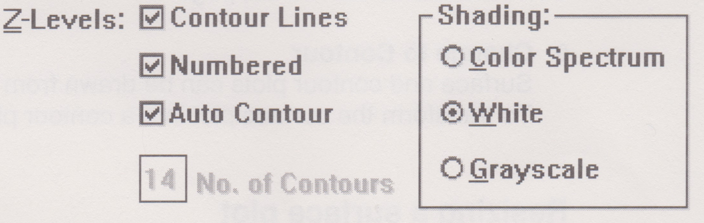
The **Min** and **Max** values determine the axis limits shown on the plot (default values **-1** and **1**).

Please note that these values have NO significance as coordinates. They affect only the labelling displayed on the axes ! (Mathcad always plots all the array values, irrespective of these limits.)

Appearance of the contour lines

You can control how many contour lines are drawn, and whether or not they are numbered with their 'height'.

When **Color Spectrum** shading is used, the colours range from red for the largest values, through yellow and green, and on to blue and violet for the smallest values.



See Mathcad file 221A3-03, page 4.

Resizing a contour plot

To change the *physical* size of a contour plot, to make it look bigger or smaller on the page, use the technique for resizing an X-Y graph (described on page 25 of this Guide).

Solving equations

How to construct equations and inequalities

	Icon	Keystroke	Description
x = y	Palette 1 [x=y]	`[Ctrl]=`	Equation ~ left- and right-hand sides equal
x ≥ y	Palette 2 [≥]	`[Ctrl]0`	Greater than or equal to
x ≤ y	Palette 2 [≤]	`[Ctrl]9`	Less than or equal to
x > y	none	`> [Shift].`	Greater than
x < y	none	`< [Shift],`	Less than

Notes – To reveal the palette 2 icons, click on button **1** at the top of the palette.

Examples		Keystroke sequence
Equation	$4 \cdot x^2 - 56 \cdot x + 192 = 96$	**`4*x^2[↑][↑]-56*x+192 [Ctrl]= 96`**
Constraint	$0 \le x$	**`0 [Ctrl]9 x`**

The solve block

The solve block is a numerical method for solving a system of equations. Mathcad '**Find**'s and displays the value of the unknown that solves the '**Given**' equations and constraints.

A block is set up as follows.

Step …			
	1	Make a reasonable guess.	$x := 1$
	2	Use the Mathcad keyword **Given**.	Given
	3a	Give the equation(s).	$4 \cdot x^2 - 56 \cdot x + 192 = 96$
	3b	Give the constraint(s).	$0 \le x$ $x \le 6$
	4	Use the Mathcad function **Find** to obtain and display the answer.	$\mathrm{Find}(x) = 2$

Notes

The keyword Given is a (black) Mathcad expression, not (blue) Mathcad text.

Mathcad looks for a solution until the error in the answer obtained is less than or equal to the built-in variable TOL (see page 15 of this Guide). Where a system of equations has more than one solution, the answer obtained may depend on the initial guess. It is also possible that a solve block fails to find an answer – this is indicated by the error message 'did not find solution'.

Instead of ending the block with Find(x)= you can make a variable definition like a := Find(x). The value of the solution (contained in a) can then be used elsewhere in the document.

See Mathcad files 121A3-02, pages 3 and 4, and 221B1-03, pages 2 and 3.

Graphical solution

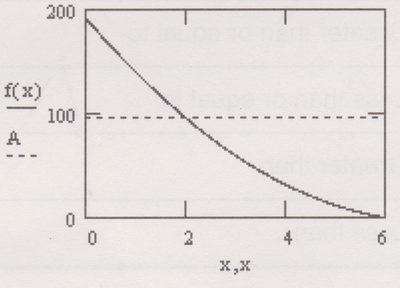
Solving the equation **f(x) = A** corresponds to finding where the horizontal line **y = A** meets the graph of **y = f(x)** . By repeatedly zooming into the graph (see page 42 of this Guide) you should be able to identify the x-value of the point of intersection.

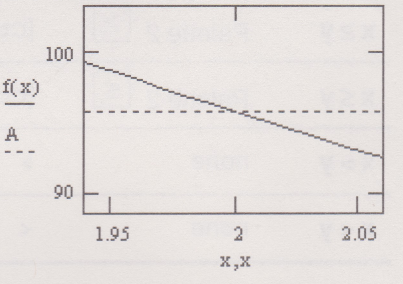
Example

Function ... $f(x) := 4 \cdot x^2 - 56 \cdot x + 192$

Target value $A := 96$ Graph range $x := 0, 0.01 .. 6$

Graph after repeated **zooming** ... the intersection occurs when **x = 2** .





Notes – The step size used to plot the graph may limit the accuracy of the solution you can obtain.

See Mathcad file 121A3-01, pages 5 and 6.

Related topic in this Guide : Graphs – Drawing, page 35.

How to use polyroots

polyroots is a built-in Mathcad function which finds the solutions to a polynomial equation. It solves equations of the form $a_0 + a_1x + a_2x^2 + a_3x^3 + ... + a_nx^n = 0$.

- The first step is to construct a vector, **a**, whose elements are the coefficients of the polynomial : $\mathbf{a_0}, \mathbf{a_1}, ..., \mathbf{a_n}$.
  To do this, either create the vector directly (see page 54 of this Guide), or define a subscripted variable for each element individually.
- The expression **polyroots(a)** then gives all the solutions to the polynomial equation.
  Unlike the solve block method, **polyroots** does not require an initial guess. Moreover, it returns numerical values for all the solutions at once, whether real or complex.

Example : solve the equation $1 + 2x - 3x^2 + 2x^3 = 0$.

Define $a := \begin{bmatrix} 1 \\ 2 \\ -3 \\ 2 \end{bmatrix}$ Solve $\text{polyroots}(a) = \begin{pmatrix} -0.317 \\ 0.909 + 0.867i \\ 0.909 - 0.867i \end{pmatrix}$

Type `polyroots(a)=`

See Mathcad file 221D1-02 and MS221 Computer Book D, Chapter D1.

Related topic in this Guide : Complex number solutions to equations, page 34.

Symbolic calculations

Preparing to work symbolically

The tools for symbolic calculations (manipulating letters as well as numbers) are provided by Mathcad's symbolic processor, using commands from the **Symbolic** menu.

Before using any of these commands, you must first load the symbolic processor.

♦ Choose **Load Symbolic Processor** from the bottom of the **Symbolic** menu.

  There will be a short delay while the loading takes place.

Once the symbolic processor has been loaded, this 'load' command will disappear from the menu. The processor remains available for use until you exit from Mathcad.

The next steps are optional, though highly recommended to help make what is going on clearer.

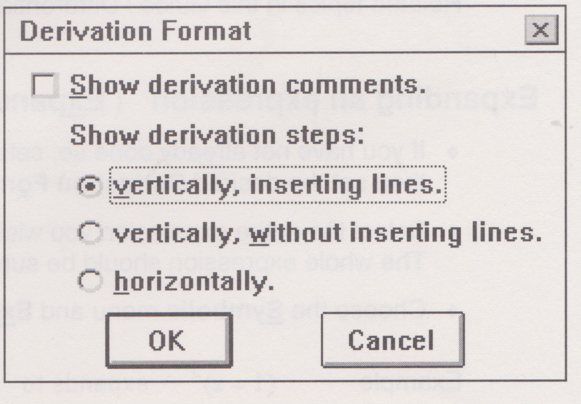
♦ Choose **Derivation Format...** from the bottom of the **Symbolic** menu.

  This brings up the 'Derivation Format' option box, which is used to control how the results of symbolic calculations are displayed.

♦ Click in the check box to **Show derivation comments**.

  This makes Mathcad insert little explanatory derivation comments when it calculates, like 'simplifies to' or 'has solution(s)'.

♦ By default, Mathcad inserts some blank lines in the document to display the result below the original expression. It can be more convenient to work **horizontally** across the page.



! The **Symbolic** menu command **Derive in Place** causes the result to replace the original expression. This is not recommended, as you can then no longer see the original expression !

Before you can actually use any of the symbolic calculations from the menu, you must select an appropriate part of a mathematical expression. Details of this selection process are included in the Guide sections on the individual menu commands which follow.

How to select a variable in an expression

To select a variable in an expression, the blue bar cursor | must be next to the variable.

- Click on any occurrence of the variable in the expression. $4\cdot x^2 - 56\cdot x| + 96 = 0$

If you have not obtained the blue bar cursor | ,
then press the 'Down Arrow' key [↓] repeatedly until it appears.

You can use the left and right arrow keys to move the cursor into position next to the variable.

How to select an entire expression

- Click on the expression ; anywhere will do.
- Then press the 'Up Arrow' key [↑] repeatedly until the blue selection box surrounds the entire expression. $\boxed{(16 - 2\cdot x)\cdot(12 - 2\cdot x) = \frac{1}{2}\cdot 16\cdot 12}$

Evaluating symbolically (**E**valuate Symbolically)

- If you have not already done so, select the **Symbolic** menu and **Load Symbolic Processor**, then set the desired **Derivation Format...** . (See the previous page for details.)
- Select the entire expression you wish to evaluate. (See above for how to do this.) $\boxed{\frac{d}{dt}\left(\frac{t^2}{9}\right)}$
- Choose the **Symbolic** menu and **Evaluate Symbolically**. (The keyboard short-cut for this command is [`Shift`][`F9`].) $\frac{d}{dt}\left(\frac{t^2}{9}\right)$ yields $\frac{2}{9}\cdot t$

Notes

This powerful command can be used to evaluate any valid Mathcad expression.

Evaluation occurs *only* when you select something and choose the command from the menu. The result of a symbolic evaluation is NOT updated if you change the original expression.

Related topics in this Guide : Differentiating symbolically, page 56 ; Integrating symbolically, page 58.

Expanding an expression (E**x**pand Expression)

- If you have not already done so, select the **Symbolic** menu and **Load Symbolic Processor**, then set the desired **Derivation Format...** . (See the previous page for details.)
- Select the entire expression you wish to expand. (See above for how to do this.) The whole expression should be surrounded by the blue selection box.
- Choose the **Symbolic** menu and **Expand Expression**.

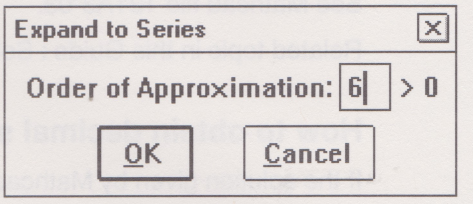
Example $(1 + x)^5$ expands to $1 + 5\cdot x + 10\cdot x^2 + 10\cdot x^3 + 5\cdot x^4 + x^5$

See Mathcad file 121A0-05, page 4.

Expanding an expression to a series (**Expand to Series...**)

This option calculates the Taylor series expansion for an expression about x = 0.

- If you have not already done so, select the **Symbolic** menu and **Load Symbolic Processor**, then set the desired **Derivation Format...** . (See page 49 for details.)
- Select a variable in the expression you wish to expand to a series. (See the previous page for help with how to do this.) $\sin(x)$
- Choose the **Symbolic** menu and **Expand to Series...** . This brings up the 'Expand to Series' option box.



- Enter the **Order of Approximation**. (To generate a Taylor polynomial of degree *n*, you need to set this order to $n + 1$.)

Finally, click **OK** to obtain the series expansion.

Example $\sin(x)$ converts to the series $x - \frac{1}{6}\cdot x^3 + \frac{1}{120}\cdot x^5 + O\left(x^6\right)$

Notes

The final 'O' term in the series expansion represents all the remaining terms in the Taylor series.

For example, $O(x^6)$ represents all the remaining terms of degree 6 and higher : x^6, x^7, x^8, ...

You should delete this term before you use the Taylor polynomial for further calculations.

See MS221 Computer Book C, Chapter C3.

Simplification (**Simplify**)

- If you have not already done so, select the **Symbolic** menu and **Load Symbolic Processor**, then set the desired **Derivation Format...** . (See page 49 for details.)
- Select the entire expression you wish to simplify. (See the previous page for how to do this.) The whole expression should be surrounded by the blue selection box.
- Choose the **Symbolic** menu and **Simplify**.

Example $\frac{20\cdot a^2\cdot b}{15\cdot a\cdot b^2}$ simplifies to $\frac{4}{3}\cdot\frac{a}{b}$

See Mathcad file 121A0-05, page 3.

Solving equations symbolically (**Solve for Variable**)

- If you have not already done so, select the **Symbolic** menu and **Load Symbolic Processor**, then set the desired **Derivation Format...** . (See page 49 for details.)
- Select the variable in the equation you wish to solve for by clicking on it. (See the previous page for help with how to do this.) $4\cdot x^2 - 56\cdot x + 96 = 0$
- Choose the **Symbolic** menu and **Solve for Variable**. $4\cdot x^2 - 56\cdot x + 96 = 0$ has solution(s) $\begin{pmatrix} 12 \\ 2 \end{pmatrix}$

The example above illustrates Mathcad's way of showing two solutions : x = 2 and x = 12.

Notes

The special equals ' **=** ' for the equation is made by using the palette 1 icon $\boxed{x=y}$ or typing [`Ctrl`]=.

Solve for Variable can be used on expressions which don't contain an equals sign !
Mathcad assumes that the expression containing the variable is equal to zero in such cases.

Symbolic calculation occurs *only* when you select something and choose the command from the menu. The symbolic solution is NOT updated if you change the equation.

See Mathcad file 121A3-03.

Related topic in this Guide : Solving equations, page 47.

How to obtain decimal solutions

If the solution given by Mathcad is NOT in decimal form, then you can evaluate it *numerically*.

- Select any part of the expression produced for the symbolic solution.
  (See page 50 for how to do this.)
- Then click on the palette 1 icon $\boxed{=}$ or type =.

Example $4 \cdot x^2 - 56 \cdot x + 192 = 144$ has solution(s) $\begin{pmatrix} 7+\sqrt{37} \\ 7-\sqrt{37} \end{pmatrix} = \begin{pmatrix} 13.083 \\ 0.917 \end{pmatrix}$

Alternatively, you can force Mathcad to give a decimal answer by entering a decimal value somewhere in the equation. Solving an equation which contains a decimal value triggers **20** figures in the solutions, irrespective of the numerical format used within the document !

Example $4 \cdot x^2 - 56 \cdot x + 192 = 144.0$ has solution(s) $\begin{pmatrix} 13.082762530298219689 \\ .917237469701780311 \end{pmatrix}$

See Mathcad file 121A3-03, page 5.

Substituting for a variable (Substitute for Variable)

This command substitutes an expression for each occurrence of a variable in another expression.

- If you have not already done so, select the **Symbolic** menu and **Load Symbolic Processor**, then set the desired **Derivation Format...** . (See page 49 for details.)
- Enter and select the expression that will replace the variable. $\boxed{x-1}$
  Then use the **Edit** menu to **Copy** it to the clipboard.
- Select any occurrence of the variable you want to replace. $u - \frac{1}{2} \cdot u^2 + \frac{1}{3} \cdot u^3$
  (See page 50 for help with how to do this.)
- Choose the **Symbolic** menu and **Substitute for Variable**.
  Mathcad will substitute the expression on the clipboard for the selected variable.

Example $u - \frac{1}{2} \cdot u^2 + \frac{1}{3} \cdot u^3$ by substitution, yields $x - 1 - \frac{1}{2} \cdot (x-1)^2 + \frac{1}{3} \cdot (x-1)^3$

Related topic in this Guide : Expanding an expression to a series, page 51.

Symbolic manipulation of matrices – inverse, determinant and transpose

To manipulate matrices symbolically, you must first **Load Symbolic Processor** and set the desired **Derivation Format...** . (See page 49 of this Guide for details of how to do this.)

There are three menu commands specifically for the symbolic manipulation of matrices : **Invert Matrix**, **Determinant of Matrix** and **Transpose Matrix**.

In each case you need to select the entire matrix *prior* to choosing the command.

- To do this, click anywhere in the matrix and then press 'Up Arrow' [↑] until the blue selection box surrounds the entire matrix, as shown. $\boxed{\begin{pmatrix} a & b \\ c & d \end{pmatrix}}$

Once the matrix has been selected, you can choose any of the menu commands shown below.

- **Symbolic** menu and **Invert Matrix**

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix} \quad \text{by matrix inversion, yields} \quad \frac{1}{(a\cdot d - b\cdot c)}\cdot\begin{pmatrix} d & -b \\ -c & a \end{pmatrix}$$

- **Symbolic** menu and **Determinant of Matrix**

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix} \quad \text{has determinant} \quad a\cdot d - b\cdot c$$

- **Symbolic** menu and **Transpose Matrix**

$$\begin{pmatrix} a & b \\ c & d \end{pmatrix} \quad \text{by matrix transposition, yields} \quad \begin{pmatrix} a & c \\ b & d \end{pmatrix}$$

Related topics in this Guide : Evaluating symbolically, page 50 ; Matrices and vectors, page 54.

Problems when working symbolically

If the command you require is not available from the **Symbolic** menu, then make sure that you have loaded the symbolic processor and have selected an appropriate part of your mathematical expression (see pages 49 to 52 of this Guide). Note that the 'Derivation Format' controls where the result will appear and whether or not comments are displayed (see page 49).

Mathcad gives a variety of responses if it is not able to carry out a symbolic calculation. In some situations (e.g. if unable to simplify an expression), it will just return the original expression as the answer. Alternatively, it may leave the answer blank or display a warning/error message. Note that during a symbolic calculation, the mouse arrow changes into a maple leaf – if you find yourself waiting a long time for any response, then you can interrupt the calculation by pressing [**Esc**], the escape key.

The warning/error messages (e.g. 'No answer found', if Mathcad is unable to solve an equation) are displayed in a small dialog box with an **OK** button – you must click on this button to return to the Mathcad document. However, one message is an important exception to this, described below.

◊ **Result special to Maple. Save in clipboard ?** – Click on the **No** button.

This dialog box indicates that the result of the symbolic calculation cannot be expressed simply, in terms of Mathcad's built-in functions – there is no need to save the result. (Maple is the name of the special software program upon which Mathcad's symbolic processor is based.)

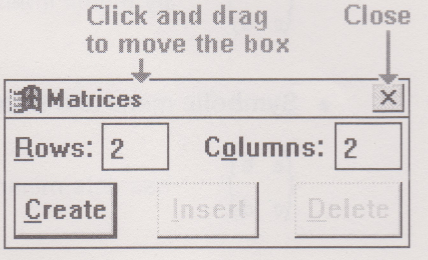
Matrices and vectors

How to create a matrix (or vector)

- To create a matrix, select the **Math** menu and **Matrices...**, or type [**Ctrl**]**m** .

  The 'Matrices' option box appears.

- Enter the number of rows and columns you require, then click on the **Create** button.



Mathcad creates a blank matrix with the appropriate number of empty placeholders. The placeholder in the top left corner is selected.

$$\begin{pmatrix} ▮ & ▪ \\ ▪ & ▪ \end{pmatrix}$$

- Fill in this first placeholder, then select the others either by clicking directly on them or by using the [**Tab**] key. The latter provides a good way of moving around the elements in a matrix : pressing [**Tab**] goes down the elements in each column in turn.

$$\begin{pmatrix} -14 & 1 \\ 4 & -2 \end{pmatrix}$$

Matrices may be created either in a blank space in a document (at the position marked by the red cross cursor) or in an empty placeholder within a Mathcad expression.
For example, to assign a matrix to a variable, do the following.
Define a variable, say **C**, and select the placeholder at the right-hand side of the definition.
Then choose the **Math** menu and **Matrices...**, and follow the procedure above to create the matrix.

$$C := ▮ \;\rightarrow\; C := \begin{pmatrix} ▮ & ▪ \\ ▪ & ▪ \end{pmatrix} \;\rightarrow\; C := \begin{pmatrix} -14 & ▪ \\ ▪ & ▪ \end{pmatrix} \;\rightarrow\; C := \begin{pmatrix} -14 & 1 \\ 4 & -2 \end{pmatrix}$$

Notes

A matrix created in this way can have a maximum of 100 elements, e.g. 10 rows x 10 columns.

Remember that a *vector* is a one-column matrix !

See Mathcad file 121B2-01, page 2.

Labelling and displaying matrices and their elements

The way in which Mathcad displays a matrix depends upon its size (the number of rows and columns). Both round and square brackets are used, and very large matrices may be shown as a scrolling table of values ; see page 29 of this Guide for further details.

Examples of labelling and displaying matrices.

Definitions		Display			
$C := \begin{pmatrix} -14 & 1 \\ 4 & -2 \end{pmatrix}$	$v := \begin{bmatrix} 5 \\ 7 \\ 11 \\ 19 \end{bmatrix}$	Type **C=**	$C = \begin{pmatrix} -14 & 1 \\ 4 & -2 \end{pmatrix}$	Type **v=**	$v = \begin{bmatrix} 5 \\ 7 \\ 11 \\ 19 \end{bmatrix}$

Matrix elements

Subscript notation is used to refer to the individual elements of a matrix.

Definitions		Display		
$C := \begin{pmatrix} -14 & 1 \\ 4 & -2 \end{pmatrix}$	$v := \begin{bmatrix} 5 \\ 7 \\ 11 \\ 19 \end{bmatrix}$	$C_{0,0} = -14$ $C_{1,0} = 4$	$C_{0,1} = 1$ $C_{1,1} = -2$	$v_0 = 5$ $v_1 = 7$ $v_2 = 11$ $v_3 = 19$

To obtain the subscripts, either use the palette 1 icon $\boxed{X_i}$ or type **[** (left square bracket).

For example, type **C[0,0=** $\quad C_{0,0} = -14$

Note that Mathcad uses the value of ORIGIN to label the first row and first column of a matrix. So with ORIGIN set as **0** (which is its default value), Mathcad refers to the top left element of the matrix as $\mathbf{C_{0,0}}$. If you change ORIGIN to 1, then Mathcad refers to this element as $\mathbf{C_{1,1}}$.

Related topic in this Guide : ORIGIN, page 15.

Matrix columns

The superscript operator **<>** (palette 2 icon $\boxed{M^{<>}}$ or type **[Ctrl]6**) extracts a column from a matrix.

Example $\quad Q := \begin{pmatrix} 7 & 12 & -8 \\ 8 & 3 & 1 \end{pmatrix} \quad Q^{<0>} = \begin{pmatrix} 7 \\ 8 \end{pmatrix} \quad Q^{<1>} = \begin{pmatrix} 12 \\ 3 \end{pmatrix} \quad Q^{<2>} = \begin{pmatrix} -8 \\ 1 \end{pmatrix}$

Note that Mathcad uses the value of ORIGIN to label the first column.

See Mathcad file 221D3-01, page 3.

Matrix operations (including inverses and determinants)

The standard Mathcad mathematical operators **+**, **-**, ***** (multiply) and **^** (powers) can all be used with matrices. In particular, raising a matrix to the power **-1** gives the matrix inverse, where it exists.

To calculate the determinant, use the '|x|' icon on palette 1, or type **[Shift]** (shift and backslash).

Examples $\quad A := \begin{pmatrix} 2 & 0 \\ 3 & 1 \end{pmatrix} \qquad$ Inverse $\quad A^{-1} = \begin{pmatrix} 0.5 & 0 \\ -1.5 & 1 \end{pmatrix} \qquad$ Determinant $\quad |A| = 2$

Notes – Applying the '|x|' operator to a vector gives the magnitude of the vector.

See Mathcad file 121B2-01, page 3, and MST121 Computer Book B, Chapter B2.

Differentiation and integration

Evaluating a derivative numerically

To evaluate the derivative of a function **f(t)** with respect to **t** at a point.

- Define the function and the value for the point. $f(t) := \frac{t^2}{9}$ Point $t := 1$
- Either click on the palette 1 icon $\frac{d}{dx}$ or type **?** (a question mark). The derivative operator appears. $\frac{d}{d\blacksquare}\blacksquare$
- Enter `f(t)` in the right-hand placeholder and `t` in the other one. $\frac{d}{dt}f(t)$
- Select any part of the expression. (See page 50 of this Guide for how to do this.) $\boxed{\frac{d}{dt}f(t)}$
- Type **=** to evaluate the derivative at the given point. $\frac{d}{dt}f(t) = 0.222$

Notes

The expression for the function may be entered directly into the derivative operator. However, make sure that the expression is enclosed in brackets to tell Mathcad to differentiate all of it. Point $t := 1$ $\frac{d}{dt}\left(\frac{t^2}{9}\right) = 0.222$

Mathcad uses a numerical algorithm to evaluate the derivative. The answer obtained is usually accurate to 7 or 8 significant figures. (The accuracy does not depend on the value of the built-in variable TOL.) If this numerical method fails to produce an answer, then the derivative is marked with the red error message 'not converging'.

See Mathcad file 121C1-01 and MST121 Computer Book C, Chapter C1.

Differentiating symbolically

There are two methods to differentiate an expression symbolically.

Before you can use either method, you must first **Load Symbolic Processor** and set the desired **Derivation Format...** . (See page 49 of this Guide for details of how to do this.)

Differentiate – Evaluate symbolically

- ♦ Either click on the palette 1 icon $\boxed{\frac{d}{dx}}$ or type **?** (a question mark). The derivative operator appears. $\frac{d}{d\blacksquare}\blacksquare$

- ♦ Enter the expression and differentiation variable in the two placeholders. $\frac{d}{dt}\left(\frac{t^2}{9}\right)$

- ♦ Select the entire expression, including the 'd/dt'. (See page 50 of this Guide for how to do this.) $\boxed{\frac{d}{dt}\left(\frac{t^2}{9}\right)}$

- ♦ Choose the **Symbolic** menu and **Evaluate Symbolically**. $\frac{d}{dt}\left(\frac{t^2}{9}\right)$ yields $\frac{2}{9}\cdot t$

See Mathcad file 121C1-01 and MST121 Computer Book C, Chapter C1.

Related topic in this Guide : Evaluating symbolically, page 50.

Differentiate on variable

- ♦ Enter the expression to be differentiated. $\frac{t^2}{9}$

- ♦ Click on any occurrence of the variable in the expression to select it. (See page 50 of this Guide for help with how to do this.) $\frac{t^2}{9}$

- ♦ Choose the **Symbolic** menu and **Differentiate on Variable**.

$\frac{t^2}{9}$ by differentiation, yields $\frac{2}{9}\cdot t$

Notes

The message 'Result special to Maple' indicates that the result of the symbolic differentiation cannot be expressed simply in Mathcad. (See 'Problems when working symbolically' on page 53 of this Guide for more details.)

Higher-order derivatives

To construct the *n*th-order derivative for a function or expression, do the following.

- ♦ Either click on the palette 3 icon $\boxed{\frac{d^n}{dx^n}}$ or type [`Ctrl`]**?** (you need to type [`Ctrl`], [`Shift`] and **/**). The derivative operator appears. $\frac{d^{\blacksquare}}{d\blacksquare^{\blacksquare}}\blacksquare$

- ♦ Fill in the placeholders for the expression and differentiation variable. Use the lower placeholder to set the order of the derivative (an integer between 0 and 5). The top placeholder is automatically filled with the value typed in the lower one. $\frac{d^2}{dt^2}f(t)$

A higher-order derivative may be evaluated numerically or by using **Evaluate Symbolically**.

Examples Point $t := 1$ $\frac{d^2}{dt^2}\left(t^3+t^2\right) = 8$ $\frac{d^2}{dt^2}\left(t^3+t^2\right)$ yields $6\cdot t+2$

Evaluating a definite integral numerically

To evaluate the definite integral of a function **f(t)** with respect to **t**.

- Define the function. $f(t) := t^2$
- Either click on the palette 1 icon or type **&** (ampersand).
  The integral sign appears with four empty placeholders. $\int_{\blacksquare}^{\blacksquare} \blacksquare \, d\blacksquare$
- Enter the function, the integration limits and the integration variable. $\int_0^1 f(t)\,dt$
- Select any part of the expression.
  (See page 50 of this Guide for how to do this.) $\boxed{\int_0^1 f(t)\,dt}$
- Type = to evaluate the definite integral. $\int_0^1 f(t)\,dt = 0.333$

Notes

An expression may also be entered directly into the definite integral. $\int_0^1 t^2\,dt = 0.333$

Mathcad uses a numerical algorithm to evaluate the integral. The accuracy of the answer obtained depends on the built-in variable TOL (see page 15). While the value of TOL does not indicate the accuracy directly, reducing TOL should increase the accuracy. If this numerical method fails to produce an answer, then the integral is marked with the red error message 'not converging'.

See MST121 Computer Book C, Chapter C2.

Integrating symbolically

Symbolic methods are available for evaluating both **definite** and **indefinite integrals**.

Before you can use any of these methods, you must first **Load Symbolic Processor** and set the desired **Derivation Format...** . (See page 49 of this Guide for details of how to do this.)

Definite integral – Evaluate symbolically

- Either click on the palette 1 icon or type **&** (ampersand).
  The integral sign appears with four empty placeholders. $\int_{\blacksquare}^{\blacksquare} \blacksquare \, d\blacksquare$
- Enter the function, the integration limits and the integration variable. $\int_a^b t^2\,dt$
- Select the entire expression, including the integral sign.
  (See page 50 of this Guide for help with how to do this.) $\boxed{\int_a^b t^2\,dt}$
- Choose the **Symbolic** menu and **Evaluate Symbolically**. $\int_a^b t^2\,dt$ yields $\frac{1}{3}\cdot b^3 - \frac{1}{3}\cdot a^3$

Notes

Mathcad finds an integral of the function and subtracts its value at the lower integration limit from its value at the upper limit. If Mathcad cannot find an integral, then it is unable to evaluate the expression. The warning message 'No closed form found for integral' is displayed in such cases. (See 'Problems when working symbolically' on page 53 of this Guide for more details.)

See MST121 Computer Book C, Chapter C2.

Indefinite integral – Evaluate symbolically

- Either click on the palette 3 icon $\boxed{\int}$ or type **[Ctrl]i**.
  (To reveal palette 3, click on the palette buttons **1** then **2**.)

  The integral sign appears with two empty placeholders.

  $\int \blacksquare \, d\blacksquare$

- Enter the expression and the integration variable.

  $\int t^2 \, dt$

- Select the entire expression, including the integral sign.
  (See page 50 of this Guide for how to do this.)

  $\boxed{\int t^2 \, dt}$

- Choose the **Symbolic** menu and **Evaluate Symbolically**.

  $\int t^2 \, dt \quad \text{yields} \quad \frac{1}{3} \cdot t^3$

Notes

Mathcad gives only an integral of the supplied expression.
It does NOT include an arbitrary constant of integration '*c*' in the answer.

If Mathcad cannot find an integral, then it is unable to evaluate the expression.
(When this occurs, Mathcad will repeat the original indefinite integral as the 'answer'.)

See MST121 Computer Book C, Chapter C2.

Indefinite integral – Integrate on Variable

- Enter the expression to be integrated.

  t^2

- Click on any occurrence of the variable in the expression to select it.
  (See page 50 of this Guide for help with how to do this.)

  t^2

- Choose the **Symbolic** menu and **Integrate on Variable**.

  $t^2 \quad \text{by integration, yields} \quad \frac{1}{3} \cdot t^3$

Notes

Mathcad gives only an integral of the supplied expression.
It does NOT include an arbitrary constant of integration '*c*' in the answer.

If Mathcad cannot find an integral, then it is unable to evaluate the expression.
The warning message 'No closed form found for integral' is displayed in such cases.
(See 'Problems when working symbolically' on page 53 of this Guide for more details.)

Menu bar commands

File Edit Text Math Graphics Symbolic Window Books Help

The following list of menu bar commands is arranged in *alphabetical* order.

It describes the commands most frequently used in MST121 and MS221 together with their keyboard short-cuts, but it does not list every Mathcad menu command.

Note that all the page references in this section are to pages in this Guide.

Edit menu

Copy	[Ctrl]c	Copy selected expression, graph or text.
Cut	[Ctrl]x	Delete selected expression, graph or text.
Go to Page...		Move through a document to the top of a specified page. (See page 9.)
Ins/Del Blank Lines...		Insert or delete one or more blank lines. (See page 18.)
Insert Pagebreak		Insert a hard pagebreak. (See page 10.)
Paste	[Ctrl]v	Paste selection most recently copied or cut. The selection can be inserted either at the position of the red cross cursor or in an empty placeholder in an expression.
Undo Last Edit [Alt][Backspace]		Undo the most recent change when editing a mathematical expression or piece of text.

File menu

Close	[Ctrl][F4]	Close the current document.
Exit	[Alt][F4]	Quit Mathcad !
New	[F7]	Create a new, empty document.
Open...	[F5]	Open an existing Mathcad file from disk.
Print...	[Ctrl]o	Print entire document or particular pages. (See page 10.)
Save	[F6]	Save current document. **!** This command overwrites an existing file with the same name on the disk with NO further prompting.
Save As...		Save current document using a new file name.

Graphics menu

Create Contour Plot [Ctrl]5 — Create an empty graph box ready for a contour plot. (See page 46.)

Create Polar Plot [Ctrl]7 — Create an empty graph circle ready for a polar plot. (See page 43.)

Create Surface Plot [Ctrl]2 — Create an empty graph box ready for a surface plot. (See page 44.)

Create X-Y Plot @ At sign [Shift]' — Create an empty graph box ready for a 2-dimensional Cartesian plot. (See page 35.)

Help menu

Note that this help is provided by the makers of Mathcad ; it is NOT specific to the course.

How Do I?... — Details of basic Mathcad procedures.

Index... [F1] — Help contents with a search facility for a particular topic.

Math menu

Automatic Mode — Switch between automatic and manual calculation modes. (See page 26.)

Calculate [F9] — Manually update all the results visible on the screen. (See page 26.)

Calculate Document — Manually update all the results in the document.

Insert Function... — Display a scrolling list of Mathcad's built-in functions from which you can select. (See page 15.)

Matrices... [Ctrl]m — Create a matrix. (See page 54 and Mathcad file 121B2-01.)

Numerical Format... — Set the display format for the results of numerical calculations. (See page 30.)

Symbolic menu

See 'Symbolic calculations' on page 49 for further details of all these commands.

Derivation Format... — Choose the format for the display of symbolic results.

Evaluate Symbolically [Shift][F9] — Carry out the symbolic evaluation of the selected expression.

Expand Expression — Expand all the powers in the selected expression.

Expand to Series... — Derive a Taylor series expansion for an expression with respect to the selected variable.

Load Symbolic Processor — Activate the symbolic processor. This command must be used prior to the *first* symbolic calculation in any session.

Simplify — Simplify the selected expression using algebraic processes.

Solve for Variable — Find the value of the selected variable in an equation that solves the equation.

Substitute for Variable — Substitute the contents of the clipboard (i.e. an expression that has been copied) for each occurrence of a selected variable in an expression.

Text menu

Create Text Region
" Double-quote **[Shift]2** — Create a new text region at the red cross cursor position. (See page 21.)

X-Y Plot menu

This menu replaces the Graphics menu when you select (in a blue box) an X-Y graph.

Crosshair... — The crosshair is used to identify the coordinates of a point on a graph. (See page 42 and Mathcad file 121A2-01.)

Format... — Set the display format for the selected X-Y graph. (See page 39.)

Zoom... — Select and magnify a portion of an X-Y graph. (See page 42 and Mathcad file 121A3-01.)

Window menu

Change Colors — Change the default colours used to display mathematical expressions and text. (See pages 9 and 21.)

Refresh `[Ctrl]r` — Refresh (re-draw) the screen to tidy it up. (See page 19.)

Zoom... — Show a magnified or reduced view of the entire document.

Palette icons

The **palette** is the strip of icons running down the left-hand edge of the Mathcad window.

There are *five* palettes in all. To reveal the other palettes, click on the number button at the top. Clicking on button **1** displays palette 2 ; clicking on button **2** in turn displays palette 3 ; and so on. Clicking on the final button **5** takes you back to the first palette.

The first three palettes are used to insert a variety of mathematical operators, whilst palettes 4 and 5 contain Greek letters for use within mathematical expressions and text.

	Palette 1 icons	Guide
1	Indicates palette number **1** – click on this icon to reveal palette 2. See Mathcad file 121A3-02, page 3.	
:=	Define (assign a value or expression to) a variable or function. See Mathcad files 121A0-04, page 3, and 121A3-01, page 2.	Page 12
=	Evaluate an expression (display the result of a calculation). Equivalent to pressing the equals ' **=** ' key.	Page 28
x=y	Separate the left- and right-hand sides of an equation. See Mathcad file 121A3-02, page 3.	Page 47
π	The value π = 3.14159... for use in calculations. See Mathcad file 121A0-04, page 3.	Page 15
m..n	Range variable definition. See Mathcad file 121A1-01, page 3.	Page 14
$\sqrt{\ }$	Square root for use in calculations. See Mathcad file 121A2-01, page 5.	
(x)	Enclose an expression in brackets.	
|x|	Absolute value of a real number, modulus of a complex number, magnitude of a vector, determinant of a matrix.	
x^y	Raise to a power. Equivalent to typing [`Shift`]`6` to obtain the ' ^ ' character.	
x_i	Create a subscripted variable. See Mathcad file 121A1-01, page 2.	Page 12
$\sum_{n=1}^{m}$	Summation See Mathcad file 121C2-01, page 2.	
$\int_a^b$	Definite integral – note that the **in**definite integral is on palette **3**. See MST121 Computer Book C, Chapter C2.	Page 58
$\frac{d}{dx}$	Derivative See Mathcad file 121C1-01 and MST121 Computer Book C, Chapter C1.	Page 56
X-Y graph icon	Create an X-Y graph. See Mathcad file 121A1-01, page 6.	Page 35

Tool bar buttons

The **tool bar** is the row of buttons immediately below the menu bar.

The buttons on the tool bar offer some alternative short-cuts to picking options from the menu.

Icon	Description	
	New	Create a new, empty document.
	Open	Open an existing file.
	Save	Save the current Mathcad document (overwrites existing file).
	Print	Print the current document.
	Undo last edit	Undo the most recent edit.
	Cut	Cut selected expression, text or region to the clipboard.
	Copy	Copy selected expression, text or region to the clipboard.
	Paste	Paste contents of the clipboard into current document.
	Align Horizontal	Align selected regions horizontally.
	Align Vertical	Align selected regions vertically.
	Text Region	Create a text region in a document.
	Paragraph	Create a text paragraph (extending across the whole page).
	Spell Checker	Check the spelling of words in text regions and paragraphs.
	Auto / Manual	Toggle **calculation modes**. When the button is DOWN – Auto , UP – Manual.
	Calculate	Update calculations displayed on the screen.
	Symbolic Evaluate	Load symbolic processor – then evaluate symbolically.
	Zoom in or out	Magnify (or reduce) the view of the document.
	List of units	List units which can be inserted into the document, e.g. m, kg.
	Help	Provide help on Mathcad features.

Errors and error messages

If Mathcad encounters an error in a document, then it displays a red error message, pointing at the offending expression.

y := 9x
error in constant

Such errors fall into two broad categories : **typing errors** and **calculation errors**.

◊ **Typing errors** can be corrected by simply editing the expression. (See page 19 of this Guide.)

◊ However, care is needed when searching for the cause of **calculation errors**.

The problem may not be in the expression marked with the error message, but may instead be due to values set earlier in the document. So you should start by looking for the error in the expression itself, then work back up the page, checking all earlier expressions, which may actually be the cause of the trouble.

Undefined variables (and **functions**)

Another common problem and source of calculation difficulties are undefined variables.

i := 1, 2 .. M

These are highlighted, as white on black.
In addition, the message 'Undefined variables shown in reverse' is displayed in the status bar at the bottom of the Mathcad window.

Likely causes of this problem are trying to assign a value using ' = ' instead of ' **:=** ', or simply a typing mistake, entering the wrong variable name. Note that names are case-specific : **M** and **m** are two different variables in Mathcad.

A variable must be defined (assigned a value) using ' **:=** ' *above* the place in the document where it is first used. See 'Defining variables' on page 12 of this Guide for more details.

This problem can also affect functions in Mathcad.

No results appear !

By default, Mathcad immediately calculates and updates all the results on the screen.

However, if you are using manual calculation mode, then you must calculate and update the screen yourself by pressing the [`F9`] function key. (See page 26 of this Guide for further details.)

Graph plotting problems – See page 38 of this Guide.

Problems when working symbolically – See page 53 of this Guide.

Refreshing (re-drawing) the screen after an error

An error message can overwrite other information on the screen.

Once you have corrected the error, this message will disappear, but the screen is not automatically restored back to its original state ; some of the information may still be missing.

To force Mathcad to refresh (or re-draw) the screen, do the following.

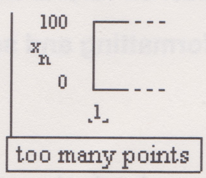
♦ Choose **Refresh** from the **Window** menu, or type the keyboard short-cut [`Ctrl`]`r`.

List of common error messages

The following list of error messages is in *alphabetical* order. It describes the errors most likely to occur in the files for MST121 and MS221, but it does not list all possible error messages.

Information about any error message is available on screen, via Mathcad's help system. To access this help, use the mouse to click on the red box containing the error message, then press the [**F1**] function key. However, please note that this help is NOT course-specific.

Error (message in red box)	**Description of error** plus suggested action to correct	**Example**
array size mismatch	An attempt was made to perform an illegal matrix operation. Check the sizes of the matrices.	$\begin{pmatrix} 5 & 7 \\ 1 & 3 \end{pmatrix} + \begin{pmatrix} 6 \\ 9 \end{pmatrix} =$ $\boxed{\text{array size mismatch}}$
did not find solution	The solve block method was unable to find a solution. Try using a different guess. However, there may be no solution.	$\mathrm{Find}(x) =$ $\boxed{\text{did not find solution}}$
error in constant	Invalid constant. Re-enter or edit value. This can also occur if you forget a multiplication sign !	$c := 9.0.5$ $\boxed{\text{error in constant}}$ $y := 9x$ $\boxed{\text{error in constant}}$
error in solve block	The solve block keywords are missing or not in correct position in document.	$\mathrm{Find}(x) =$ $\boxed{\text{error in solve block}}$
illegal function name	The function could not be evaluated by Mathcad. Make sure that it is defined.	$g(7) =$ $\boxed{\text{illegal function name}}$
illegal range	Range variable could not be interpreted. Check range values. The number after the comma must be between the start and finish of the range.	$n := 1, 2..0$ $\boxed{\text{illegal range}}$
index out of bounds	A subscript or superscript which refers to a non-existent array value. Check values used for subscripts.	$b_{13} =$ $\boxed{\text{index out of bounds}}$
interrupted	Mathcad calculation interrupted by you pressing the [**Esc**] key. Calculations can be re-started by pressing the [**F9**] key.	$s_{n+1} := 1.05 \cdot s_n$ $\boxed{\text{interrupted}}$

misplaced comma	A comma has been used in an illegal place. A comma may be used to separate only the first two elements of the range.	$n := 1, 2, 12$ misplaced comma
missing operand	A value is missing from an expression, a range or a graph placeholder. Fill in the placeholder.	$n := 1, \blacksquare .. 12$ missing operand
must be integer	A non-integer has been used where an integer value was expected. Check calculations to see if a subscript takes a non-integer value.	$m_{10.5} =$ must be integer
non-scalar value	An array has been used where a scalar is required. Check use of subscripts. Replace array (b) with a scalar (b_{n+1}).	$b := b_n + 3$ non-scalar value
not converging	Mathcad is unable to compute an answer for a derivative or integral.	$\frac{d}{dt} f(t) =$ not converging
overflow	The value is too large to handle. Mathcad can handle only numbers of magnitude of about 10^{307}.	$2^{10000} =$ overflow
singularity	An expression has been evaluated at an illegal value, e.g. division by zero. Avoid calculation for this value.	$f(x) := \frac{1}{x}$ $f(0) =$ singularity
subscript too large	Subscript used exceeds Mathcad's internal limit. Reduce maximum size of subscript.	$N := 10^9$ $n := 1, 2 .. N$ $x_n := 2^n$ subscript too large
too few arguments	A value is missing from the function. Check the number of values required.	until(1) = too few arguments
too few constraints	There is not enough information to solve the equation(s) within a solve block. Try increasing the number of constraints.	Find(x) = too few constraints
too many points	Mathcad cannot handle the number of points in one graph. Plot fewer points !	

Notes – See page 65 for help with **undefined** variables or functions. $i := 1, 2 .. M$ $F(3) =$

Quick reference

Documents

Use the **File** menu to create a **New** blank document, **Open...** an existing one, **Save As...**, **Print...** and **Close**.

Mathematical operators

Add **+**   subtract **-**   multiply ***** `[Shift]8`   divide **/**   powers **^** `[Shift]6`

Use **.** (a full stop) for the decimal point, and round brackets **(** and **)** to group terms.

Entering text

Select the **Text** menu, **Create Text Region** or type a double-quote **"** `[Shift]2` – then enter your text.

Defining variables / functions

	Icon	Key	Example	Key sequence
Define (assign a value to) a variable	:=	**:** colon	$A := 30$	`A:30`
Subscripted variable	X_i	**[** left square bracket	$u_0 := 1$	`u[0:1`
Range variable	m..n	**;** semicolon	$i := 0, 1 .. 10$	`i:0,1;10`
Function	:=	**:** colon	$f(x) := 4 \cdot x^3$	`f(x):4*x^3`

Evaluating an expression

Icon	Key	Example	Key sequence
=	**=** equals	$4.8 \cdot 9 = 43.2$	`4.8*9=`

Displaying tables

To display a sequence of values u_0, u_1, u_2, ..., as a (scrolling) **table of values**, type `u=`

To display the values as an **output table**, define a suitable range k and display u_k=, e.g. type `u[k=`

Number formatting

Click **in** the table or expression to select it. Choose the **Math** menu, and **Numerical Format...**

Editing and selecting expressions

Click **on** the expression.

Then keep pressing [↓] 'Down Arrow' to obtain blue bar cursor | (insertion point). $1 + x| + x^2$

To edit, use [←], [→] and `[Backspace]` or `[Delete]`.

[↑] 'Up Arrow' to select entire expression in the blue selection box. $\boxed{1 + x + x^2}$

Drawing X-Y graphs

Define a suitable graph range.

To create an X-Y graph, click on the palette 1 icon or type @ `[Shift]'`

Enter x-axis expression(s) in middle placeholder on horizontal axis, y-axis expression(s) in middle placeholder on vertical axis – to plot more than one curve, separate expressions with commas.

Graph formatting and scaling – Click **in** the graph to select it (surrounded by blue box).

To **format** the graph traces or axes, choose **X-Y Plot** menu, **Format...**

To fix the **scale**, edit the four axis limit placeholders.

Symbolic calculations

Start with **Symbolic** menu, **Load Symbolic Processor** and set **Derivation Format...**

Then either select a variable in an expression or select the entire expression prior to a symbolic calculation.